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DWELLING HOUSES: THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS.

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I.

SITUATION AND CONSTRUCTION OF HOUSES.

It is only necessary for me to make a few introductory remarks about climate. Although few persons can choose what part of the world they will live in, a considerable number are able to decide in what part of the country they will reside. Other things being equal, the nearer a place is to the sea, the more equable is the climate, and the further inland the place is, the more is the climate one of extremes; so that those who wish for a moist, equable climate, with warm winters and warm nights, will choose a place by the seaside; while those who wish for a more bracing atmosphere will go further inland. In England, too, there is considerable difference, as is well-known, between the climate at various parts of the seaboard. Thus, the western coast, being exposed to the winds which pass over the Atlantic, and to the action of the moist, warm air which passes over the course of the Gulf Stream, has a warm, moist atmosphere, and a heavy rainfall; while the eastern coast, which is swept by winds that have passed across Siberia and Russia, and have only the narrow strip of German Ocean to pass over before they reach our coast, has a dry, bleak, and comparatively cold climate.

For the same reason, too, the exposition of a house, or the way in which it faces, is a matter of great importance in this climate, as is well-known; a southern exposition, for example, being warm and genial, whilst an eastern one is just the reverse.

In the neighborhood of forests, the air is damp during a great part of the year, from the enormous amount of evaporation that takes place from the leaves of the trees, and Humbolt tells us that the large forests on the banks of the Amazon are perpetually covered with mist. Other things being equal, a bare, open country is drier and hotter than a well-wooded one.

I will divide the soils, for sanitary purposes, into two kinds—pervious and impervious; those that allow water to pass freely through them, and those that do not. Pervious soils are such as gravel, sand, and the less compact and softer limestone, which allow water to pass through their interstices, and chalk, in which the water, for the most part, travels through the fissures; and the typical impervious ones, such as the

various clays, mostly named from the localities where they are best known, as the London clay, Oxford clay, Kimmeridge, clay. Most of the metamorphic rocks and the hard limestones are non-porous, but have a multitude of crevices, through which the water finds its way. In the former case, the water which falls on the surface passes readily through the soil, until it comes to some impervious stratum below, over which surface it passes, until it either finds outlet at the surface of the ground where the impervious stratum crops out, or until it reaches the nearest watercourse, so that above the impervious layer, which has arrested its progress through the rocks, there is a stratum of water of a depth which will vary with a variety of circumstances—a stratum which can be reached from the surface of the ground by digging wells down to it. This water we call the "subsoil" water, or the ground water (*grundwasser*). In some instances, the impervious stratum just spoken of is placed in such a manner as to prevent the escape of the subsoil water at all, in which case the soil is said to be water-logged. The water which falls on the impervious soils, on the other hand, does not sink into the ground, but remains on the surface, or runs off if there be a suitable incline, and so such soils are necessarily damp. The diseases that are prevalent upon the pervious soils are enteric (typhoid) fever and cholera; during epidemics of that disease—diseases, in fact—the poisons are chiefly communicated by means of drinking water; and the readiness with which the subsoil water just mentioned can be contaminated by the percolation into it of foul matters from the refuse of habitations, combined with the fact that people who live on such soils, as a rule, drink water from wells dug in them, no doubt accounts for the prevalence of those diseases.

On impervious, damp soils, on the other hand, consumption, the great plague of our climate, which kills more than half as many people as all the communicable fevers put together, is prevalent, and so are lung diseases of various kinds—rheumatism, and, under special circumstances, ague. It has been clearly shown that dampness of the soil under the houses is one of the great factors in the production of consumption. Dr. George Buchanan (see 9th report of the Medical Officer of the Privy Council) demonstrated that in every instance where the level of the subsoil water in a town has been lowered, that is to say, where the distances between the basements of the houses and the level of the water in the soil had been made greater, the death rate from consumption had decreased—in one instance to the extent of not less than 50 per cent., so that there can be no question that it is extremely important for everyone who can to live upon a dry soil. Where, then, the soil is not pervious to a considerable depth below the basements of the houses, so that the level of the ground-water comes within a few feet of them, or where the soil, being itself pervious, is naturally water-logged, or in the so-called impervious soils, which are, of course, all pervious to some extent, it is necessary to provide mains whereby the level of the water shall be kept below a certain minimum depth from the foundations of the houses. This is done by drainage, and by a drain I mean a pipe or channel that is intended to remove the water from the soil. It must, therefore, be a pipe into which the water can get—that is to say, it must be pervious to water. The object of drains, then, is twofold, to carry off the surface water, and to prevent the subsoil water rising above a certain height, for as soon as it rises to the level of the drains it finds its way into them, and is carried away to the outfall at a lower point.

Drains may, therefore, be made of stones placed together without cement, as was the case with the Cloaca Maxima, the great drain which was constructed by the second king of Rome to dry the ground around the Forum; or of brickwork, with or without mortar; or, as is very commonly the case, of pervious agricultural tiles. The surface gutters must also be mentioned in connection with the drains, and they are, of course, especially necessary on impervious soils. The ultimate destination of the drains is into the watercourses, streams, rivers, &c.

So much for natural soils; but, especially in the neighborhood of most of our large towns, many of the houses are built upon artificial soil, or "made

ground" as it is called. This made ground consists of the refuse of dust-bins, ash-pits, midden-heaps, and the like, which is shot at some place where the ground requires to be raised. It is very undesirable that houses should be built on any such made ground, at any rate for a considerable period. There is no doubt, however, that, after some time, the action of the air and water in the soil causes a slow decomposition of the organic matters in it, and renders it less objectionable as a site for building purposes. Nevertheless, no one would choose to live in a house built upon "made soil" if he could help it.

The proximity of buildings is the next matter to be considered. It is important that houses should not be too near together, as otherwise both light and ventilation are interfered with, and it is now a regulation in the metropolis that a new street shall be at least as wide as the houses on either side of it are high, and that no new street shall be less than forty feet wide.

Having determined the site on which to build, we come next to the foundations. These should not be on made ground, nor on purely vegetable soil, as peat, humus, &c. Their depth is a matter which it is the architect's province to determine, and depends upon various circumstances, such as the weight they have to support. The material used must be the best concrete. The inferior kinds, made with too little lime or cement, crumble away, allow damp air to pass through them, and make the house unwholesome, besides endangering the structure. It is important to remark here that a house should not be built, or even its foundations laid, in frosty weather, for the work will not hold when a thaw sets in.

Basement.—The covering of the ground with some impervious material is imperative, in order that the moist air from the soil may be prevented from rising into the house. In the case of made soils, the covering of the ground should extend for some distance round the house. This covering is best made of concrete some inches thick, and should be used in all cases, whether there are any underground rooms or not. Such underground rooms or basement floor should only be used as cellars—not as living rooms—and should always be arched. The concrete floor may be covered with asphalte, tiles or York paving, but wooden floors should never be used below the ground level. The walls of the house, below the level of the ground and a little above it, should be made with exceptionally good materials, and set in cement, so as to be as impervious as possible to damp. This is a matter that is very frequently lost sight of, and the walls below the level of the ground are frequently made of the worst possible materials. Being hidden from sight, it is often considered that the best materials need not be used for them. It is advisable to have a damp course in the walls all round the house, at a little distance above the ground level, whether the site be a damp one or not. This damp course may be made of asphalte, stoneware, or slate set in cement. Cement alone cannot be depended on. If such a course is not placed in the wall, moisture will rise up through the bricks by capillary attraction, and make the walls of the house damp, rendering the house itself unwholesome. The inner side of the walls in the basement floor may be advantageously made of glazed bricks or of hard black Staffordshire bricks, but no covering of any kind whatever should be placed on those walls. The money should be spent on good construction, and not on covering up bad materials. There should be a dry area all round the walls of the house outside, starting from the concrete foundations. Its width is a matter of little importance, as it is only required to ensure dryness of the walls below the level of the ground, and the ventilation of the cellars in the basement, unless, indeed, the basement rooms are inhabited, in which case, at any rate, the regulations of the Public Health Act must be complied with. This area must have proper connections with the land drains to allow of the removal of the surface water. The materials used for building the walls of the house depend upon the locality. They may be bricks, stone of various kinds (the choice of which must be left to the discretion of the architect), and, in some parts of the country, flint. Bricks stand fire better than anything else, for the simple reason that they have been already burned.

This fact was remarkably shown in the great fire at Chicago, where the brick houses remained comparatively intact, while the granite ones were utterly destroyed. In any case the materials should be set in mortar or cement, and in wet and exposed positions the walls should be double or "hollow" walls, as they are technically termed. Occasionally, in such positions they should even be slated on the outside, or covered with glazed tiles. Walls are sometimes made of concrete, a very ancient plan, and not modern, as is commonly supposed. The Romans frequently used concrete walls in their aqueduct bridges and other constructions. The cement used was of extraordinary hardness, and has, I believe, never been surpassed, even if equaled, in later times. It might be called the "cement of the Romans," as the term "Roman cement" is now commonly applied to a very inferior article. In making concrete columns, the Romans adopted the practice of inserting layers of their flat bricks, which we should perhaps call tiles, at intervals, and they faced the surface with stones, generally disposed after the fashion known as *opus reticulatum*. This consisted in placing small cubical blocks of stone against the surface of the concrete, so that the sides of the exposed faces were not vertical and horizontal, but the diagonals were, thus giving the appearance of network, or of a chess-board set up on one corner. These devices assisted greatly in protecting the structure from the weather, and from rough usage. Such walls may also be very well faced with tiles of various kinds.

The chimney flues should be as straight as possible. They should be separate from one another—a matter very often not attended to—and they are better lined with pipes, as these are much more easily cleaned; an updraught is more readily established in them, and they completely disconnect the flue from the structure of the house, and so help to prevent destruction by fire.

It is important that the chimneys should be higher than the surrounding buildings, so that the wind may pass freely over them, and that they may not be sheltered from its action in any direction whatever. If this is not the case, there will be a down draught in the chimneys when the wind is in a certain direction, and the more the chimneys are sheltered by high buildings the more chances there are of down-draughts in them. If necessary, an iron or zinc pipe called a "tall-boy," may be placed on the top of the brickwork, to increase the length of the flue. This is sometimes even carried up adjoining buildings, and is, as a general rule, better without a cowl of any kind on the top of it, as will be further explained in the next lecture.

Flooring.—Fire-proof floors are most desirable. They may be made of concrete or brick arches between iron girders, in which case there is no space between the flooring of one room and the ceiling of the room below. When timber is used, it should be dry and well-seasoned, with sound boarding, to ensure a separation between the rooms, and to prevent either water leaking from the floor to the ceiling below, or air passing from the room below to that above. Good flooring evidently serves to protect the ceilings of rooms below. Where there is space between the flooring and the ceiling, and still more especially where a wooden flooring is placed over a concrete or other foundation laid on the ground, it is necessary to provide for ventilation of the space below the flooring. This is usually done by placing a perforated iron grating, instead of a brick, here and there, in the outer walls, so that air can pass freely in or out below the floors. For this purpose bricks, such as those exhibited, with conical holes through them, would no doubt be found very useful.

The Roof.—This may be constructed either of fire-proof materials, or of timber, and in either case may be covered with slates or tiles, or may be thatched; copper or corrugated iron are also used. Sometimes zinc is used on account of its cheapness. It is not a good material, as it does not last long. Lead is largely used, especially upon flat roofs, and is valuable an account of its lasting properties. Where there are eaves, it is important that they should not drip on to the walls, but project, so as to throw the water off. Cornices and all projections should be constructed so as to throw off the rain, or it will run down the walls. If this is not done, the

walls will be continually damp and dirty. Rain-water gutters may be made of lead or iron. They must have a sufficient fall, and shoot directly into the heads of the rain-water pipes. They should be wide enough inside to stand in, so that the snow may be cleared out. If this is not done, it will accumulate, blocking up the channel, and when the thaw comes the melted snow will work its way through the tiles or slates of the roof, and injure the ceilings below.* Rain-water gutters should not be carried through the house from one side to the other, and especially not through bedrooms. Nor should they be carried, as is sometimes done, round the house inside the walls, and through the rooms. A more or less disagreeable smell is frequently noticed in rooms through which rain-water gutters pass. The rain-water pipes should also be outside the house. They should be of iron, well jointed. Galvanized iron ones are preferable; they are only a little more expensive and last much longer. They should either discharge into rain-water tanks, which must be well ventilated, or on to the surface of the ground or area round the house. They should not be connected directly with the drains or sewers. Neither should they be placed with their hoppers or heads just below the bedroom windows, especially if they discharge into a tank. Large and high houses, especially if standing alone, require to be provided with lightning conductors. Copper ones are better than iron, and need not be so thick. They must be insulated from the walls of the house by suitable rings of some non-conducting material, and end in some moist place in the soil. In the case of an isolated house it is also a good plan to have a weathercock on the roof, and connect that with a registering apparatus in the hall. An anemometer is also useful.

Thus far about the construction of the building itself. We now come to the finishing off inside. The floors should be covered with boarding—oak bees-waxed being the best, or deal, stained and varnished, may also be used. The joints are better tongued. Parquet flooring, made of teak, may be placed over the whole of the surface, the object being to ensure, as far as possible, a uniform and impervious surface, without cracks or badly made joints, in which dust can accumulate. This is especially important. Either of these plans is better than the common one of covering the whole floor with a carpet or drugget. When these are used, a border of stained and varnished or polished boards, or of parquet flooring, should be left all round the room. This has the advantage that dust does not accumulate so readily in the corners, which are more easily swept and cleaned, and the carpet can be taken up at any time to be beaten, without moving the furniture which is against the walls. The skirting boards of wooden floors should be let into a groove in the floor. This will serve to prevent draughts coming through, and dust accumulating in the apertures, which are invariably formed by the shrinking of the joints and the skirting. Some floors, such as those of halls, greenhouses, &c., are best tiled.

Wall Coverings.—These, like the floors, are better made of impervious materials which can be washed. Tiles form an admirable wall covering, and are, moreover, a permanent decoration. Various kinds of plastering, with the surface painted, form a cheap and effective wall covering. Paint containing lead should, of course, not be used, but the silicate, or the indestructible paints, and zinc white should be used instead of white lead. Paper as a covering for walls has the disadvantage that, as a rule, it cannot be washed, and that the dust collects on it. For this reason, after a case of infectious disease, it is necessary as a general rule to strip the paper off the walls, whereas a painted or tiled wall can be washed. Many papers, too, are colored with arsenical paints, and seriously affect the health of the persons living in the rooms, the walls of which are covered with them. For a considerable amount of information on this subject I would refer to a little book which has just appeared, entitled "Our Domestic Poisons," by Mr. Henry Carr.

Ceilings.—For these plastering is in most general use. It is better painted than distempered. Whitewashing, however, answers very well, and can be repeated as often as necessary. Paper

* The remark as to the width of gutters does not apply to eaves-gutters.

should not be used for covering ceilings. If they are of wood it should be paneled, or the joints will let the dust through. The wood work generally throughout the house should be stained and varnished, polished, or painted; and generally I may sum up the principles to be followed in finishing off the inside of a house by saying, that the materials should be, as far as possible, impervious, and the surface smooth and uniform, and so disposed as to be easily cleaned, and not to collect the dust.

VENTILATION, LIGHTING, AND WARMING.

The air in our houses is rendered impure in various ways, but chiefly by our respiration, and by the products of combustion that are allowed to escape into it from lights and fires. The air that we expire contains a certain quantity of foul, or putrescent, organic matter. It is charged with moisture, and contains about five per cent. less oxygen and nearly five per cent. more carbonic acid than the air that we inspire. It is neither the diminution of oxygen nor the increase of carbonic acid in the air of rooms that is of the greatest importance to living beings, but the accumulation of foul organic matter and the excess of moisture. It is this which renders such atmospheres stuffy, and not the diminution of oxygen or the increase of carbonic acid, which are so slight as to be of little importance, even in overcrowded rooms. Nevertheless, since the increase in carbonic acid is proportional to the increase in other impurities, and since we can estimate very accurately the amount of carbonic acid in the air, the increase of carbonic acid is taken as an index of the impurity of the atmosphere. The average amount of carbonic acid in the outer air is four parts in ten thousand. Professor De Chaumont found by his experiments that, whenever the amount of carbonic acid in the air of a room exceeded the amount in the outer air by more than two parts per 10,000, the air of the room was not fresh, that is, say, that the foul organic matter in it and the excess of moisture were sufficient to make the room stuffy. Hence, two parts of carbonic acid per 10,000 of air, over and above that in the outer air, are taken as the limit of respiratory impurity. As an adult breathes out, on the average, six cubic feet of carbonic acid in ten hours, it is clear that, in order that the air of the room in which he is may be kept fresh, he must have 30,000 cubic feet of air in the ten hours, or 3,000 per hour. In this climate we cannot change the air of a room more than three or four times per hour without causing draught, and so each person ought to have from a thousand to 750 cubic feet of space, the air of which should be changed three or four times per hour respectively. The way in which this space is arranged is also a matter of some importance. For instance, the air above a certain height is of little use for purposes of ventilation, if combined with too small a floor space. To take an extreme case—a man standing on a square foot of ground, with walls 3,000 feet high all round him, would be in 3,000 cubic feet of space; but it is quite obvious that he could not live in it. But, even without any enclosure at all, and without any limit as to height, it is not difficult to conceive a place overcrowded. For instance, all the inhabitants in the world, men, women, and children, could stand upon the Isle of Wight; but it is quite certain that they could not live there, even if it were only for the want of air. So it is usual, in estimating cubic space, to disregard the height above eleven or twelve feet. It is also obviously of importance that the floor space should be properly distributed; but, about this, so far as dwelling-houses are concerned, there is no need to enter into particulars. We are not able to insist on anything like 1,000 or 750 cubic feet of space in all instances, and amounts varying down to as low as 300 cubic feet per individual are adopted. In the case of a family living in one room, which is so small as to afford less than 300 cubic feet per individual, it is usual to consider that the limit of overcrowding which should be allowed by law has been reached. We cannot have, as a general rule, rooms so large that the air does not require changing while we are in them. Thus, for instance, a person in a bedroom for seven hours consecutively requires about 21,000 cubic feet of air if the atmosphere is to be kept fresh. Supposing him to have this without change of air, he would require a room, say, 70 feet long by 30

wide and 10 high. This makes it quite clear that in rooms such as we have there must be a change of air.

In studying ventilation from a practical point of view, the chief agents that we have to consider are the winds, and movements produced in the air by variations in its density, usually brought about by variations in its temperature; the property of the diffusion of gases by means of which the air is brought to a uniform composition when the temperature is the same throughout, being one which, practically speaking, does not affect the question much. With artificial methods of ventilation, in which the air is forced in a certain direction by machinery, we have little to do, as few of them are suitable for use in dwelling houses. The wind, as an agent of ventilation, is powerful, but its disadvantage is that its action is irregular. When all windows and doors can be opened, a current of air which may be imperceptible, is quite sufficient to change the air of a house in a very short time, and houses that have windows on both sides are for this reason much more healthy than houses built back to back, which can never have through ventilation. This is the direct action of the wind, which may generally be utilized in large rooms with windows on opposite sides, like schoolrooms, by opening that which is nearest to the direction from which the wind comes, a little way at the top, and also opening the one which is diagonally opposite to it at the top a little further than the first one. The direct action of the wind has also been utilized for ventilating large houses by Silvester's plan, which consists in having a large cowl, that always faces the wind, at the top of a pipe leading down into cellars in the basement of the house, where the air can be warmed by stoves, and allowed to ascend into the house. By this plan the holds of ships are frequently ventilated. But the aspirating action of the wind is, perhaps, of greater importance. When the wind blows over the top of a chimney, or over a ventilating pipe, it causes a diminution of pressure of the column of air in the chimney or ventilator, and so produces an up-current, upon precisely the same principle that little bottles made for distributing scent about apartments act. For this reason, it is, as was hinted in the last lecture, important that chimneys should be higher than the surrounding buildings, so that any wind that blows may cause or increase an up-draught in them. In this way not only is smoke prevented from ascending into the rooms, but the amount of air carried through rooms up the chimneys is increased, and the ventilation of the house improved. There being, then, in every house, and frequently in every room, a shaft—whether sufficient or not, we will consider by-and-bye—for the escape of air, it becomes of the first importance for us to consider the means by which air may be admitted into our houses and into our rooms. In summer, and whenever the air is as warm outside the house as inside of it, there is no difficulty about this. We have only to open the windows—wind-doors, remembering the proverb that "Windows were made to open and doors to shut"—on both sides of the house, and the air is generally changed fast enough, but it is in winter, when the air is colder outside the house than inside, that the difficulties arise, and so in speaking of ventilation I shall always assume that the air outside the house is colder, and therefore heavier, and exercises greater pressure than the air inside it. This being the case, it follows that if we open a window, or make an aperture through a wall into the outer air, or through the wall of a room into a passage, or staircase, in which the air is colder than it is in the room, air will come in. In fact, a room under these conditions may be looked upon as if it had water outside of it, and it is quite apparent that, in such a case, if you bored a hole through the wall into the water on the other side, water would come in, and the air of the room would escape by the chimney. This is precisely what happens with the cold air outside. If no special opening is provided through which the cold air can come into a room, it enters by such openings as there are; by the apertures between the sashes of the windows, by the—perhaps fortunately—badly fitting doors, crevices in the floors, walls and cupboards, through the walls themselves, as has been shown by Pettenkofer, and sometimes down the chimney. If, then, air will come in through an aperture placed in any position, it becomes necessary to consider

where apertures should be placed, and what precautions are necessary with regard to them. Theoretically, the admission of pure air should be at the lowest part of the room, and the extraction of the vitiated air, which is warm, at the upper part of the room; but practically the outer air cannot be admitted without certain precautions at the lower part of the room by mere apertures, as everybody knows who has been accustomed to sit in a room when a draught comes under the door. On the other hand, if an aperture is made into the outer air through a wall at a few feet from the floor, the air enters in a cold straight current for some distance into the room. If the aperture be higher up, it comes in and falls, just as water would do, on to people's heads, somewhere about the middle of the room. So it is quite clear that certain precautions are necessary in the admission of air so as to prevent draughts. Since we have, or ought to have, windows in all rooms, it will be convenient to consider, first, the ways in which they may be utilized for the admission of air. We cannot simply open a sash window at the top or bottom in cold weather without feeling a draught, but there are several ways in which this difficulty may be got over. The simplest is by placing a board of wood underneath the lower sash, as suggested by Dr. Hinckes Bird, whose original model I have here. This board is sometimes now made with a hinge in the middle, so that it can be got in and out more easily; or the board, instead of being placed under the lower sash, may be placed across, from side to side, in front of the lower part of the lower sash, so that the lower sash may be opened to a certain height without any air coming in below it. These boards may be covered with green baize, or some other suitable material, so as more perfectly to prevent the entrance of the air at the lower part of the window. In either case, the bars of the sashes at the middle of the window are no longer in contact, and air comes in at the middle of the window, between the two sashes, taking an upward direction, in the form of a fountain, and producing no draught. This shows us the direction in which cold air ought to be admitted into a room—after the fashion of a fountain, in which it can be readily obtained, owing to its greater pressure, and not after the fashion of a waterfall.

This simple plan, which I recommend very strongly for adoption, has two disadvantages, one that nervous people always fancy there is a draught if they see anything like a window open, and the other a much more practical one, but one that is common to most forms of ventilation that are inexpensive—that a certain quantity of blacks enter. These conditions are, to a certain extent, got over by the plan suggested by several inventors—of boring holes through, or cutting pieces out of the lower bar of the upper sash. Such holes are not seen; and the air comes through them in a vertical direction into the room. They can also be fitted with little boxes containing cotton wool, through which the air will be filtered and deprived of soot, etc. This, of course, very considerably diminishes the amount of air that enters, and the cutting also weakens the framework of the window. I may here mention Currall's window ventilator, which consists of a metal plate fastened along the lower bar of the lower sash, and parallel to it, with an opening below the sash for the admission of air, which is thus deflected into a vertical direction by the metal bar. Here will be also a convenient place to mention the automatic sash fastener patented by Messrs Tonks & Sons, by means of which the window is securely fastened when opened to the extent of three or four inches, either at the top or bottom, so that the window can be left open without any one outside being able to open it further. This can also, obviously, be combined with the window block placed underneath the lower sash, so that air can be admitted in the proper direction, and the window still be securely fastened.

Louvred ventilators may also be used in a variety of ways in connection with windows. Where there are venetian blinds, it is only necessary to open the top sash, pull the venetian blinds down in front of the opening, and place the louvres so that they give the entering air an upward direction. Glass louvres fixed in a metal frame work, may also be used, a pane of the window being taken out and one of these ventilators substituted for it. The louvres can be opened and shut by means of a string, and they are

so fixed that it is impossible to break them by doing so. They are generally fixed instead of one of the top panes of the upper sash. It is better to place them lower down in the upper sash; and this is true of all inlets of air. If they are too high up, the air being admitted in an upward direction, impinges against the ceiling, rebounds into the room, and produces a draught. The metal frame work of these ventilators requires oiling and attending to, or it will get rusty. In some places fixed louvres of wood, or still better, of strong glass, may be fixed with advantage, or swinging windows with sashes hung on centers may be used, as, for example, in water closets; and these, where it is advisable, may be prevented from being closed by a means of a small wedge of wood screwed to the frame work. The blind so often placed across the lower part of a window may also advantageously be used as a ventilator, or, where no blind is required, a glass one may be used, this being made to swing forward on its lower edge, so as to give the entering air an upward di rection when the lower sash is opened, as in the model here shown, which was presented by Messrs. Howard to the Parkes Museum. Where very large quantities of air require to be admitted, one or more sashes of a window may be made to swing forward in this way, as is now done in the large hall of Willis's Rooms. Near to all windows, in the cold weather, the air of the room is colder than at other parts of the room. This may be obviated, when considered advisable, by the employment of double windows, the layer of air between the two windows preventing, to a very considerable extent, the cooling of the air inside the room. It is not advisable to have double panes of glass in the same sash, as the moisture between them will render them more or less opaque in certain states of the weather. With double windows, air may be admitted by opening the outer one at the bottom and the inner one at the top. Where French casement windows are used, as they sometimes are unadvisedly in this climate, ventilation may be provided by having a louvred opening above the casements of the window, or by making a glass pane or panes capable of being swung forward on the lower edge. Lastly, Cooper's ventilator is largely used for windows, and also in the glass panes over street doors. It consists of a circular disk of glass, with five holes in it, placed in front of a pane of glass with five similar holes, and working on an ivory pivot at its center. It can be moved so that the holes in it are opposite to those in the window pane, when air will, of course, come in; or, so that they are opposite to the places between the holes in the panes, when the air will be prevented from entering. It is obvious that the air is not admitted in an upward direction, but the disadvantage of this is partly counterbalanced by the fact that it is admitted in five small streams, and not in one large one, so that there is less probability of a draught.

The air may also be admitted through apertures made in the walls or doors. The simplest way to do this is to make a hole through the wall, and fasten a piece of board in front of it in a sloping manner, so as to give the air an upward direction. It is better to put "cheeks," as they are called, on the sides, for they serve not only to attach the sloping board to the wall, but to prevent the air from falling out sideways into the room. This ventilator may be hidden by hanging a picture in front of it, and will cause no draught. I may state here that it is better in a large room to have two or more small ventilators of any kind whatever than one large one, and that no single inlet opening should be larger than a square foot. Openings of half that size are preferable. It is calculated that there should be 24 square inches of opening per head, so that a square foot would be sufficient for six persons. In such an opening as has been described, wooden or glass louvres may be placed. The same end may be attained by making one of the upper panels of a door to open forwards with hinges to a certain distance; or, even in some instances, by fixing it in this position. An obvious disadvantage, and one which always has to be considered in making openings through walls and doors is, that conversation which goes on in the room can be heard in the passage outside. Sherringham's valve is a modification of this plan, and can be fitted either into an outer wall or into one between the room and the passage or hall. It consists, as you see, of a metal box to fit into the hole in

the wall, with a heavy metal flap, which can swing forwards, and is exactly balanced by a weight at the end of a string passing over a pulley, the weight acting as a handle, by means of which the ventilator can be opened or shut or kept at any desired position. What has been said before applies to these ventilators. They should not be placed too near the ceiling, and this is the mistake that is generally made in fixing them. Stevens' drawer ventilator may also be mentioned here. The name almost describes it. It resembles a drawer, which is pulled out of the wall for a certain distance, and allows air to come into the room vertically in several streams between metal plates placed inside the drawer. Jennings' "Inlet," which is in use in the barracks, consists of an opening through an outer wall, into a chamber in which dust, etc., is deposited, and thence between louvres into the room. Here I may mention that it is sometimes advised to place perforated zinc or wire gauze outside the entrance to the ventilators, so as to prevent dust, etc., coming into the room. This is not advisable, as the apertures get clogged up, and the en trance of air is much impeded. It is better to have an iron grating which will prevent birds entering, and to employ other methods for preventing the entrance of dust, soot, etc. Where this is considered necessary, the plan of passing air through cotton wool, which must be frequently changed, may be adopted. Currall's ventilator for admitting air through the door is sometimes useful. It resembles his window ventilator almost exactly; a long slit is cut through the door, a perforated metal plate placed outside, and a flat plate fixed parallel to the door inside and in front of the slit, thus giving the air as it comes into the room an upward direction. An admirable plan for the admission of air into rooms is by means of vertical tubes—an old system, but one which has been brought into prominence of late years by Mr. Tobin. A horizontal aperture is made in the wall into the outer air just above the floor, and then a vertical pipe carried against the wall to a height of from four to five feet. The cold air is thus made to ascend like a fountain into the room. It does so in a compact column, which only perceptibly spreads after it has got some height above the mouth of the tube. It then mixes with warm air at the top of the room, producing no draught at all. In spite of the vertical height through which air has to pass before it emerges into the room, a considerable amount of soot and dust of various kinds is brought into the room. This may be obviated by placing a little cotton wool. in the interior of the tube. This, however, although a very efficient plan, has the serious disadvantage of impeding the current of air. A better plan is the one patented by the Sanitary Engineering and Ventilating Company; a tray containing water is placed in the horizontal aperture in the wall, the entering air being deflected on to the surface of the water by metal plates. The greater part of the dust is thus arrested by the water, which can be changed as often as necessary. In warm weather ice may be placed in the trays. Another plan is to place in a vertical tube a long muslin bag with the pointed end upwards, and kept in shape by wire rings. This provides a large filtering area, and offers very little resistance to the passage of air. The bag may be taken out and cleansed as often as necessary.

Several contrivances have been devised for the admission of air close to the floor, just behind a perforated skirting board. Among these are Ellison's conical ventilator, shown in the last lecture, and Stevens' skirting board ventilator, in which metal cups are placed in front of the inlet openings, and so distribute the air that no draught is felt. I think, however, that it is only advisable to admit warmed air at a low level into rooms, but there is no reason why such openings should not be made high up in the rooms—behind cornices, for example. Pritchett's paving, made of agricultural pipes, may also be used for making walls and partitions, and is obviously applicable for ventilation purposes, whether used as inlet or outlet.

We now come to speak of exit shafts and valves. The first and most important of these is the chimney, about which I have already spoken. I need only add here that it is advisable to do without the use of cowls upon chimneys wherever it is possible. If the chimney can be made high enough it will not require a cowl, and if it cannot, a

simple conical cap is generally sufficient to prevent down draughts. There is no doubt, however, that Boyle's fixed chimney cowl for preventing down draught not only does so, but produces an up draught in the chimney when the wind blows down upon it, as I can readily show you by an experiment with the model I have here. A small piece of wool is made to ascend in a glass tube by blowing vertically down upon the fixed cowl placed upon the top of it. Of revolving cowls for chimneys, the common lobster-backed cowl is probably the best. Whilst speaking of cowls, I may as well mention that a variety of cowls, some of which I have here, have been invented with the object of increasing the up draught in exit shafts of various kinds, some are fixed, as Boyle's, Buchan's, and Lloyd's, and some revolving, as Scott, Adie & Co's., Howarth's, Stidder's, Banner's, Stevens', and the one invented by Mr. Boyle, but discarded by him some years ago. Whether any of these cowls increase the up current in exit shafts is a matter which is still under investigation, but I can show you, quite easily, that the common rough experiment, by means of which they are supposed to do so, is entirely fallacious. Cotton wool is drawn up a tube at least as easily by blowing across it in a slanting direction as by blowing through a cowl placed on the top of it. The fixed cowls have the advantage that they cannot get out of order. The revolving cowls have the disadvantage which is common to all apparatus with moving parts, that they are certain to get out of order some day or other. Whether they increase up draughts or not, there is no doubt that most of them prevent down draughts, and, like any other cover, prevent the entrance of rain.

Openings are sometimes made high up in the room into the chimney flue and protected by valves, the best known of which is Arnott's valve, which consists of a light metal flap, swinging inside a metal frame work in such a way that it can open towards the chimney flue, but not towards the room. Any pressure of air from the room towards the flue will, therefore, open it and allow the air to escape from the room into the flue. Pressure of air the other way will shut it. The disadvantages of this ventilator are that it makes an irregular noise, although this has been, to a considerable extent, obviated by the india-rubber padding with which it is now fitted. It also occasionally admits a little soot, and, of course, air at the same time, from the flue into the room. Boyle's chimney ventilator, made by Messrs. Comyn, Ching & Co., is a modification of this. Instead of the light metal flaps, there are a number of small talc flaps. These make little or no noise, but they are liable to be opened by a current of air in the chimney. It is obviously, it seems to me, at variance with sound sanitary principles to make openings from the interior of the room into the chimney flues, and then to trust to valves for preventing the air of the flue from coming in. A far better plan is to have shafts placed by the side of the flues, and this, of course, is better done when the houses are built. The easiest and most satisfactory way of doing it is by means of air and smoke flues combined, in which the air flues are molded in the same piece of fire-clay as the smoke flue itself. These air flues can be connected with the upper parts of the rooms, and up draughts will be inevitably caused, as the air in them will be considerably heated on account of its immediate contact with the outer side of the flue. Such shafts can only serve as inlets when the flues are cold, and so it is advisable to use them especially with flues that are always hot—as, for instance, that of the kitchen chimney—and it is desirable, wherever it can be done, to connect the kitchen with a different air-shaft from the other rooms, or it is possible that air from the kitchen may get into some of the other rooms of the house.

Of exit ventilators not connected with the chimney flues, I may mention Mackinnell's, which also provides an inlet for air as well, and which is very useful in little rooms, closets, etc., having no rooms over them. It consists of two tubes, one inside the other, passing through the ceiling into the outer air. The inner one is larger than the outer one, and projects above it outside and below it an inch or so into the room. At its lower end a circular rim is attached horizontally parallel to the ceil-

ing. The outer air enters between these two tubes, and is deflected by the rim just mentioned along the ceiling, so that it does not fall straight into the room. The vitiated hot air passes out by the inner tube, the action of which is, of course, considerably increased if a gas burner or other light be placed beneath it. It is upon this principle that the lamps for lighting railway carriages are made, the reflector answering the purpose of the rim round the end of the inner tube, and the air to supply the lamp coming in between the reflector and the glass shade, while the products of combustion escape through the pipe leading from the middle of the reflector, and immedietely over the flame. Of course Mackinnell's ventilator requires a cover to keep out the rain, and it is necessary, in fact, to have a double cover, so that the heated air which escapes by the inner tube shall not be carried back into the room by the entering air. Tossel's ventilator is a variety of this, with a cover by means of which the action of the wind is able to be taken advantage of. The same inventor has also contrived one which can be used between the ceiling of one room and the floor of the room above, provided that this space can be well ventilated.

This brings us naturally to say a little about lighting. Candles, lamps, and gas, help to render the air impure. It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men, or even more. This is why it is commonly considered that gas is more injurious than lamps or candles, and so it is when the quantities of light are not compared, but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles. If, in the dining-room, instead of using five or six gas burners, as we too often do without any provision for the escape of the products of combustion, we used 40 or 50 sperm candles instead of 6 or 8, we should have a fairer comparison between gas and candles.

I have no time to enter into a discussion of the relative merits of various kinds of candles and lamps, but with regard to gas I would say that, considering the fact I have just stated, it is always advisable to provide a means of escape for the products of combustion immediately over the gas burners. By this, not only may these products be carried away, but, with a little contrivance, heated air may be drawn out of the room at the same time, and so an efficient exit shaft provided, in addition to the one found already in the chimney. Very simple contrivances will answer this purpose. A pipe, with a funnel-shaped end, starting from over the gas burner, and carried straight out into the open air, with a proper inlet opening, is all that is required in some instances, as in badly placed closets. For large rooms, the sunlight ventilators are found to answer admirably. They should be provided with a glass shade, placed below them to intercept the glare, and to cut off a large portion of the heat. An elegant contrivance for dwelling-rooms is Benham's ventilating globe light. In this, the products of combustion of the gas pass along a pipe, placed between the ceiling and the floor of the room above, into one of the flues. This pipe, being surrounded by another opening into the ceiling of the room at one end, and into the flue at the other, is guarded at its entrance to the flue by a valve which can be easily shut when the gas is not burning. This double tube, as it passes under the floor of the room above, is covered with a fire-proof material, so that the floor is not affected by it. The joists, where they are notched, have iron bearers put across to support the floor boards above. Air is admitted by another pipe passing through the wall of the house into the external air, and ending also in the ceiling of the room by openings around those of the exit shaft. Thus warm air is introduced into the room at the same time that vitiated air from the upper part of the room, and also the products of combustion of the gas, are carried out of it into the chimney flue.

I may say a few words about some grates and stoves that have been devised with the view of combining ventilation and heating. The first of these is Captain Douglass Galton's grate, in which there is an air chamber placed around the flue, and communicating on one side

with the external air, and on the other with the atmosphere of the room by various apertures. The outer air which passes into this chamber is warmed by contact with the heated flue, and issues into the room, thus supplying the room with warmed air, and utilizing a considerable quantity of the heat that would otherwise be lost. There are several other grates, such as the Manchester school grate, made upon this principle, with variations in the arrangement of the inlet apertures, which are placed vertically like Tobin's tubes, etc. It is important in all these contrivances, where the outer air passes through a chamber in which the back of the grate and the flue is placed, that the back of the grate and the commencement of the flue in that chamber should be cast in one piece of metal, so as to have no joint. If there are joints they will become after a time defective, and air from the flue is liable to escape into the chamber round it and be brought back into the room by the entering air. Some slow combustion stoves, as George's "calorigen," have air pipes passing through them, and have the external air warmed on its way through the stove into the room. Iron slow-combustion stoves dry the air too much, and unless they are lined with fire-clay, are apt to become too hot, and to cause an unpleasant smell in the room by the charring of the organic matter in the air. They are much more suitable for warming large buildings, where economy of fuel is an important object, than they are for use in sitting-rooms or offices. It is usual to place a vessel of water on the top of these with the view of obviating, as far as possible, the dryness of the air that they produce. It must be borne in mind that closed slow combustion stoves do not act as ventilators, as the air to supply the fuel—usually coke—is brought by a pipe from outside, and this is another reason why they are not so advantageous as an open fire or a quick combustion stove in dwelling-rooms. In the Thermhydric grate of Mr. Saxon Snell, a small boiler is placed behind the grate, and communicates with a series of iron pipes alongside of it. These are filled with water, which is, of course, kept warm, and air is admitted to the room between these hot water pipes. Thus, it is neither dried nor heated too much. The products of combustion are carried away by a flue, which may be placed under the floor; so that the grate, if required, may stand in the middle or in any other part of the room.

Gas stoves are gradually becoming largely used instead of coal, and, when proper provision is made for the escape of the products of combustion, they are certainly very convenient, and cleanly contrivances. I have no doubt that this will, in the end, be found to be the proper use for gas, and that we shall cease entirely, or almost entirely, to use coal in our houses. By using coal in the way that we do, we lose all the valuable bye-products—the ammonia, the tar, the carbolic acid, aniline dyes, etc., which are derived from the refuse of gas works, and which are worse than useless to us in our fires. Gas may be burned either mixed with air or not. In the first instance, a gas stove or grate filled with pumice-stone or asbestos does not much resemble an ordinary fire, but if the gas be burned unmixed with air it is almost impossible to tell the difference. Generally speaking, it is found necessary, when there are several gas stoves in a house, to have a special supply of gas with larger pipes for them. What the gas companies should do is to lend gas stoves of various kinds, especially cooking stoves, to their customers for a small annual payment, as is done very successfully in Continental cities. It is important that gas cooking stoves should not give an unpleasant smell of unburnt gas as some do. This is not only a waste but a nuisance, as coal gas always contains carbonic oxide (an extremely poisonous substance), and should, therefore, not be allowed to escape into the air, even in the smallest quantity.

I have now to mention an artificial system of ventilation which has been lately introduced by Messrs. Verity Brothers. It consists essentially of a fly-wheel fitted with fans or veins. The wheel is made to revolve by a jet of water directed against it, and supplied from a cistern overhead, the water passing off by a pipe into a cistern below. The apparatus can be fixed either in an inlet opening, and so made to propel air into the apartment through an

aperture in the wall placed higher than people's heads, and made in a slanting direction, so that the entering air is shot upwards towards the center of the room; or it can be used as an extractor, by placing it in an exit shaft, and causing it to draw the vitiated air out. The supply of water can be regulated by taps, to the greatest nicety, so that the wheel can be made to revolve at whatever speed is desirable. The entrance pipes are sometimes fitted with a vertical tube containing a box, in which ice can be placed, or a holder for perfume, or any deodorant. For smoking rooms it is found advisable to use the apparatus as an extractor only, and to allow the air to come in by means of Tobin's tubes.

Dwelling-houses are seldom warmed and ventilated by means of hot-water apparatus, and so I do not think it necessary to enter into a description of the plans by which this may be effected. I need only mention Mr. Pritchett's "miniature hot water apparatus," if I may so call it, by means of which a single room may be warmed and ventilated. The water starts from a small boiler, the size of an ordinary kettle, which may be placed on a fire anywhere, or heated by a spirit lamp, and passes through a narrow space between double cylinders, the inner cylinders being used for the admission of fresh air, which is warmed in passing through them, or for the extraction of foul air. The water is made to pass through the extraction cylinders first, while it is hottest, and then through the others and back to the boiler. The cylinders are placed vertically, so that the air is admitted into the room in the proper direction. Other systems of artificial ventilation are suited for large public buildings, but are not adapted for use in dwelling-houses.

For the purpose of these lectures we must assume that it is necessary to have a sufficient supply of water that is fit to drink for all uses. The obvious characters of a good drinking water are that it is clear, transparent and colorless without taste (that is to say, neither salt nor sweet), and without smell, that it has no suspended particles in it, and produces no deposit on standing, and that it is aerated; but a water may possess all these characteristics and yet be unfit to drink, by reason of dissolved matters which cannot be detected except by chemical analysis, but the existence of which may often be suspected from a knowledge of the history of the water. Waters are commonly divided into hard waters and soft waters. Hard waters are those which contain a considerable quantity of mineral salts, especially salts of lime in solution; soft waters those which contain much smaller quantities of these substances. Very hard waters are unfit for domestic purposes. A deposit of mineral matters takes place in the supply pipes, etc., and they get blocked up. Such very hard waters, too, are not desirable either for drinking or for domestic purposes generally. Moderately hard waters appear to be as wholesome as soft waters for drinking purposes. The Registrar-General has shown that the death-rate, in towns supplied with moderately hard water, does not differ sensibly from that of a series of towns supplied with soft water, but in other respects similar in their sanitary arrangements. Nevertheless, animals in their natural state prefer soft water to hard, and those who have the care of horses always give them soft water to drink if possible. An undoubted disadvantage that attends the use of hard water for domestic purposes consists in the enormous waste of soap that it entails. In order to wash with soap, it is necessary to produce lather. Now, the mineral salts in hard water decompose the soap, and form insoluble compounds, so that solution of the soap in water which will form a lather, does not take place until the lime, etc., in the water has been deposited as insoluble lime soap, etc. Thus the more salts of lime and other mineral matters are present in the water, the more soap is wasted before the formation of a lather. This can be easily illustrated by a simple experiment. If we take a sample of distilled water, which contains no mineral matters in solution, and add a certain measure of an alcoholic solution of soap to it—when we shake the bottle in which it is, a lather is immediately produced and remains for some time; but when we take the same quantity of another sample of water, and add the soap solution to it, we find that it requires, in this instance, about twenty

times as much of the solution to form a lather. (Experiment shown.) Soft water then, on the whole, must be preferred to hard for domestic purposes, and when the water is very hard it ought to be softened before being distributed. This may be done by Clark's process, which consists in adding milk of lime to the water as long as a precipitate is formed. The *rationale* of this is that most of the hard waters contain considerable quantities of carbonate of lime, which is held in solution in the water by the means of free carbonic acid. The lime added as milk of lime combines with the free carbonic acid, forming more carbonate of lime, which, together with the carbonate previously in solution, is deposited, being almost entirely insoluble in water. As it is deposited, it carries down with it any suspended matters that may be in the water, and so leaves the water clearer and purer. A practical difficulty in the carrying out of this process, arising from the length of time required for the precipitate to subside, has been overcome by a process of filtration devised by Mr. Porter, and known as the "Porter-Clark process." Water, after being distributed, may be softened to a considerable extent on a small scale by boiling, when the carbonic acid gas is thrown off, and the carbonate of lime deposited. It is this which causes the incrustation of boilers. The boiling also helps to purify the water in other ways, and it is a very good plan to use boiled water, either when the water is very hard, or when there is any suspicion of impurity, both for drinking and for domestic purposes generally. It may be aerated by allowing it to fall from a height from one vessel into another. The average quantity of water required in a community is generally put down at from 30 to 35 gallons per head daily. Of these, from 20 to 25 are required for household purposes (including waste), where baths and water closets have to be supplied, and ten or more are necessary for washing the streets, for flushing the sewers, and for trade purposes.

The important sources of water are: (1.) Rain collected directly. This is of course very soft water, and in country places very pure. In towns it is rendered impure by the substances that it washes out of the air, and must be filtered before it is used, but it is everywhere an important and valuable source of soft water which is far too much neglected. It ought to be collected and used for domestic purposes, and wherever there is any suspicion as to the quality of the water supplied from other sources, rain water should (especially in the country) be used for drinking. It may be filtered through sand, gravel or charcoal by means of very simple contrivances.

(2.) Water is often obtained from shallow wells dug in the soil, down to a little below the level of the subsoil water. These, of course, drain the soil around for a greater or less distance, and the water in them frequently becomes contaminated by foul matters from leaky sewers, cesspools, etc., especially in pervious soils. Persons should therefore always be suspicious of the quality of water derived from shallow wells, for frequently, even when bright and sparkling, it is highly contaminated.

(3.) Springs and small streams are often used to provide supplies of water, and very pure water is obtained in this way, although it is sometimes rather hard. It is either conveyed directly to the town by means of aqueducts or pipes, after the Roman plan, or collected from a gathering ground into large impounding reservoirs, and thence taken in pipes to the place to be supplied.

(4.) The water of large rivers is now frequently used as a source of supply. It is received in settling basins or reservoirs, where a deposit takes place, then filtered through beds of sand and gravel, and afterwards distributed. Most of the river water is contaminated in various ways during its passage through towns; and, without entering further into the subject here, I would merely say that it is better to obtain water that has not been contaminated, than to take water which we know has been contaminated, and then try to purify it.

(5.) Water is sometimes obtained from pervious water-bearing strata, at a considerable depth below the surface of the ground, by boring into them through the impervious strata which lie over them, and through which the water cannot penetrate. Wells with such borings from the bottom of them are known as artesian walls, from having been first generally used in the French province of Artois. The water contained in such

water-bearing strata is supplied by the rain which falls on the outcrop of these strata, often at a considerable distance, and, frequently, as in London and Paris, on the hills around. This water percolates through the pervious rocks, and so gets beneath the impervious strata which lie over them after they have disappeared beneath the surface, and, being retained there under pressure, rises through borings made into the rock in which it is, through the impervious strata lying over it. This water, then, is generally, as may be expected, very pure, although it is frequently, especially if derived from the chalk, as that supplied by the Kent Company to London, very hard. Occasionally, as in some wells bored into the New Red Sandstone, it contains too much common salt to be fit for domestic purposes, which will not be wondered at when we consider that the largest deposits of salt we have, from which enormous quantities are obtained, are in the New Red Sandstone formation.

However the water is obtained, it is distributed to the houses in one of two ways, either by intermittent or by constant service. With the system of intermittent service, the water is turned on into the houses once or twice in the twenty-four hours for a short period each time. It is, therefore, necessary to have cisterns, butts, tanks, or receptacles of some kind to keep the water in during the intervals. In these, deposit occurs of the suspended matters contained in the water, and dust accumulates, especially if they are not covered, or if the covers are broken, and so the water is rendered impure. They also usually have a waste or overflow pipe, which is frequently connected with the sewers or with some part of the water-closet apparatus, and by means of which foul air finds its way into the cistern and contaminates the water. During the intervals, too, when the mains are not charged with water, foul water and foul air find their way from the soil around through leaky joints, and contaminate the water when it is next turned on, so that it frequently happens that the first water that comes into the cistern when it is turned on is quite unfit to drink. There is an enormous amount of loss with this system, which might, however, in great part be prevented. The last disadvantage of the intermittent supply lies in the fact that some delay is frequently experienced in obtaining water for extinguishing fires.

With the system of constant service, on the other hand, the pipes are always full, and so it is not necessary to have cisterns, or receptacles of any kind for the storage of drinking water, although this is frequently done. Receptacles are, however, necessary for the supply of water to closets. The pipes being always full of water under pressure, are far more likely to leak out into the soil than to be contaminated with foul matters from the soil. Still, it is not advisable on any account that water-pipes should be carried near to sewers or other sources of contamination. The water is fresher, and purer, and cooler in summer when supplied on the constant service system. The pipes are full in case of fire, and the inspection of pipes, taps, and other fittings is, as a matter of fact, carried on very much better, and less waste of water takes place under this system (although the pipes are always charged) than under the other system. It is obvious that, unless there were very strict supervision, a great waste of water would necessarily accompany the use of the constant system. For this reason, also, the water companies that have adopted that system will not allow waste pipes from cisterns to be connected with the sewers, or closet apparatus, but insist on their discharging freely in the open air; and usually in some place where any waste water running out of them would produce annoyance, so that it would be speedily noticed, and the cause of the waste remedied. It is very important, however, where this system is adopted, that there should be double reservoirs or tanks, in order that one may be used while the other is being cleared out; for if, as has been the case at some places, and notably at Croydon, the water be supplied by the intermittent system of service for a few days, defects which have produced no inconvenient results while the constant system of supply was practised (such as the connections of water-closet hoppers directly with the main water pipes), the possibility of the existence of leaky joints in the mains, through which foul matters may enter from the soil, etc., may produce the gravest results by spreading enteric fever throughout the

community; and here I may mention that it is, of course, extremely improper and very dangerous to convert a cistern which is used to supply drinking water, or a water supply pipe, directly with the hopper of a water closet. The system of constant service is coming gradually into more general use, and it is very probable that water meters will be much more generally used than they are at present. A simple apparatus of this kind is Ahrbecker's water-meter, in which the water is made to pass through oblique apertures in a fixed plate into oblique or spiral passages in a cylinder which is capable of rotating, and the axle of which turns the index of a dial. The pipes, by means of which the supply of water is conveyed into the houses from the mains, are usually made of lead; this material being preferred on account of its durability, and the facility with which it can be bent in various directions. A disadvantage of it is, that certain waters attack and dissolve lead, and are thereby rendered more or less poisonous. Those, however, are chiefly pure and soft waters. Waters containing mineral salts in solution, such as those generally supplied for drinking purposes, scarcely attack lead at all; and, moreover, with waters which do attack lead, the surface of the metal becomes covered with an insoluble coating of oxide and carbonate, which protects it from further attack. Pipes made of lead lined with a thin layer of tin are sometimes used, but when the tin becomes damaged in any way, a galvanic action is set up, and the lead is dissolved quicker than ever. Varnishes of various kinds have been proposed for coating the interior of water mains and pipes. Most of them are very objectionable—one of them positively containing arsenic. Wrought iron pipes with screw joints are sometimes used for water pipes. They are certainly cheaper than lead, and it is said that they will last longer. Bends are made of almost every possible shape just as in gas pipes. In some rare instances lead pipes are attacked from the outside by water containing carbonic acid in the soil, as shown in a sample of a lead pipe which had been laid in chalk, and which was contributed to the Parkes Museum by Mr. Bostel, of Brighton.

The receptacles used for storing drinking water are made of various materials. Leaden cisterns have long been frequently used on account of their durability. They are open to the same objections as lead pipes, although from the fact that no mischief has been found to result from the use of lead pipes and cisterns at Glasgow, since it has been supplied with Loch Katrine water, which is exceedingly soft, it appears probable that the ill-effects from the use of lead in this way have been exaggerated. Galvanized iron cisterns are fast taking the place of leaden ones. They are very durable, and of course far cheaper than lead. Stone or even brickwork lined with cement are sometimes used at or below the ground level for the storage of water, and are open to no objections so far as the material is concerned. Stoneware cisterns are now made, and are admirably suited for cottages, for use in basement floors, etc. Slate cisterns are not unfrequently used for upper stories, as well as ground floors. Of course, slate in itself is an excellent material for such a purpose, but slate cisterns, unfortunately, are very apt to leak after a time, and the joints are then filled in with red lead from the inside of the cistern—a practice which is, of course, very objectionable. The use of wooden receptables, such as tubs, butts, etc., ought to be discouraged, if only because they are difficult to be kept cleansed. A self-cleansing tank is sold by the Sanitary Engineering and Ventilating Company. The bottom, instead of being flat, is made to slope from all sides towards the center, where the waste pipe is fixed. On lifting up, by means of a lever, that part of the waste pipe which stands up in the cistern, and which is fitted accurately into the commencement of the pipe at the bottom of the cistern, so as to make a water-tight joint, the water runs out of the cistern, and on account of the sloping bottom washes all the sediment away with it. The water is generally supplied to the cistern from the pipes through a tap known as the "ball valve." To it is attached, by means of a metal bar, a hollow copper sphere or ball, which floats on the water as it rises in the cistern, and when it has risen to a certain height turns off the tap. It is because these taps are liable to get out of order, that a waste or overflow pipe is necessary. This waste or overflow pipe should, in all cases, without any ex-

ception, discharge freely, as over an area, etc., so that you can see the water coming out at it. All receptacles of water should be well covered, in order that dust may be kept out of them. Nevertheless, ventilation space between the water and the cover, by means of holes provided with a grating, at the sides, is advisable.

Of course, for drinking water, we ought to choose a source of supply that is unpolluted. As Mr. Simon has said, "It ought to be an absolute condition for a public water supply that it should be uncontaminable by drainage." We ought not, then, to take confessedly impure waters and try to purify them, so as to make them fit to drink. On the other hand, it is obviously unnecessary to use very pure water, except where there is a superabundance of it, for washing the streets, flushing the sewers, and supplying the water closets, and so it may be advisable in some places to have a double supply of water, one of pure water for drinking and cooking, derived, for instance, from artesian wells, and the other of an inferior character for other uses. This has been lately proposed for London, and whatever may be said against it on the score of expense, I think most people will agree that it will be very desirable to have water to drink which has not been first polluted with sewage and then filtered. The advantage of this plan, too, was perfectly well recognized by the ancient Romans. Frontinus tells us that it pleased the Emperor (as he puts it) to order that the water supplied by certain aqueducts should be furnished to the people for drinking purposes, while that supplied by some others, from its being occasionally turbid and of inferior quality, was to be used for "viler purposes."

As, however, we do not, as a matter of fact, in the majority of instances, imitate the ancient Romans, either in this particular or in bringing pure water from a distance to supply the towns, but use the nearest water that we can get, whether good, indifferent, or bad, it is of course necessary for us to do all that we can to purify it before use. This is done on a large scale by filtration through layers of sand and gravel, after the coarser suspended matters have been allowed to deposit themselves in a settling tank. I shall not describe this method of filtration in detail here, as it is a little beside the scope of these lectures, but, as the principle on which it acts is the same as that upon which the success of most forms of domestic filter depend, I may say a few words about it once for all. The experiments made by Dr. Frankland for the Rivers Pollution Commissioners showed that when foul water was passed through layers of porous soil, or sand and gravel, the amount of organic matter in it was reduced, if two conditions were fulfilled; these are, that the filtration be downwards and intermittent. It was found that if the filtration were upwards or continuous no such purification occurred after a time. The explanation of these facts is simple. The filtering material acts in two ways. It separates mechanically suspended matters in the water that are too large to pass through the pores of the filtering material, and it also acts chemically by means of the oxygen of the air in its pores, when, as the water flows downwards through the filtering material, it percolates through by means of a number of very small streams, and so is brought into the most immediate contact with the oxygen of the air in the filtering material. Thus, the organic matter and ammonia dissolved in the water are oxidized with the production of nitrates and carbonates, and it is certain that by this means a considerable quantity of organic matter is reduced to a harmless condition. Domestic filters, clearly, ought not to be required. The water ought to be delivered sufficiently pure to drink.

And here I would remark that the average quality of a drinking water supplied to a place is not the matter of most importance, and, indeed, is rather a fallacious guide. What we want to know is the quality of the worst sample that the public are likely to be supplied with at any time. But it is not only because the water supplied varies in purity, in most instances, sometimes considerably, that domestic filters are useful, but because, as I have before remarked, especially where the intermittent system of supply is in vogue, the water, even if delivered pure, is rendered impure in the houses themselves by being stored in filthy receptacles. The majority of the filters in domestic use rely upon the

principle of downward filtration. In a few the water is passed upwards through a filtering material. The chief materials used are animal charcoal—vegetable charcoal is not a good material for filtering purposes—silicated carbon, carbide of iron, spongy iron and sand. When animal charcoal is used, it must be specially prepared and well burned. If any of the animal matter be left in it, it becomes, as has been shown by the Rivers Pollution Commissioners, a breeding place for myriads of small worms which pass into the water. With the other materials mentioned, there is, of course, no risk of this, as they are made of burnt shale, or taken from the interior of blast furnaces. Some filters are placed inside the cisterns, so that all the water that is drawn off has to pass through them. These are placed on the main water pipes themselves, or in the taps. One of the former kind known as "the self-cleansing filter," in which the suspended particles in the water are prevented from getting at the filtering material by a ring of compact silicated carbon, and the water itself is made to wash the outside of the block of filtering material through which it has to pass. My experience goes to prove that filters that are always under water, cease to purify the water after a time, unless means are taken for aerating them, and in many instances I have known water to be rendered more impure by its passage through a filter which had been used in this way for a considerable time. Of forms of domestic filter, the glass decanter with a solid carbon or silicated carbon block has the great advantage that every part of it can be seen, so that it can be kept scrupulously clean. These filters will go on working perfectly well for an almost unlimited time, scarcely anything being necessary beyond cleansing the surface of the block once now and then with a hard brush. It is a very good plan to have a kind of double filtration. Sometimes the water is made to pass through a piece of sponge before falling on to the filtering material with the view of arresting the coarser suspended matters. It is far preferable, however, to use the carbon block for this purpose. In Prof. Bischoff's spongy iron filter the filtering material is always under water, and the action which goes on in it is certainly quite different to that which I have explained, and is as yet little understood. The River Pollution Commissioners have expressed the highest opinions of this substance as a filtering material. On account of the fact that the water dissolves a little of the iron on its passage through the spongy iron, it is made to pass through a layer of prepared sand afterwards, with the view of removing this, and then, in order to aerate it, it is delivered through a very small hole in a fine stream into the pure water receiver. It will thus be seen that it is rather more complicated than some of the other forms of domestic filter. The slight trace of iron that remains in the water can hardly be considered a disadvantage, at any rate in large towns.

Lastly, I must notice the filter made by the General Sanitary Engineering and Ventilating Company. In this, by an ingenious contrivance, the air passes to and from the filtered water chamber through the filtering material itself, and not by means of a small channel in the china or earthenware vessel holding the filtering material, as is the case in other filters. The water first passes through a silicated carbon block, and then falls in the form of a shower on to the surface of a layer of some loose silicated carbon supported upon a perforated plate which is not flat, but has elevations here and there on its surface. The result is, that not only when the water is drawn off by the tap does air pass through the filtering material into the filtered water chamber, but also as the water flows through into this lower chamber it forces the air out through the filtering material itself, which it is enabled to do by means of irregularities on the surface of the plate upon which the filtering material rests. If this plate were quite flat as it was heretofore made, and if there were no air pipe from the lower chamber, a balance would be established, and both water and air would cease to pass through the filtering material.

When rain water is used for drinking, and even for other domestic purposes, it is advisable to filter it, and the best form of filter for this purpose is one devised by Professor Rolleston, of Oxford. The tank to receive the rain water has two compartments, divided from one another by a vertical partition, and each having a

horizontal layer of filtering material, as charcoal placed on a perforated support half way down the tank. The rain-water pipe from the roof is brought down through this filter bed nearly to the bottom of one of the compartments. The rain water then has to pass upwards through the filtering material in this compartment over the partition into the second compartment, and downwards through the filtering material there, into the lower part of that compartment, where there is a tap from which it may be drawn off. An overflow pipe is, of course, provided, so that the water cannot rise above a certain level.

In conclusion, I need only say that the number of instances in which epidemics of typhoid fever, cholera, and some other diseases, have been traced to the use of impure water, or of milk contaminated with foul water, must make it evident to everyone that it is of the greatest possible importance that we should have uncontaminated sources of water.

THE ELECTRICAL TRANSMISSION OF MOTIVE POWER.

From "Engineering."

THE transmission of motive power to a distance is a subject which has, for many years, occupied the minds of mechanicians, and, until very recent times, with only very barren results. Yet this question is one of the greatest commercial importance, for a system which can, with any pretence to economy, transmit mechanical energy from one spot where there is an abundance of power with but little or no work whereby it may be utilized to another place where there is plenty of work but no power to drive it, would create a mechanical revolution in many countries, and would give to certain parts of the earth new manufacturing industries by which their internal resources might be developed to an extent hitherto altogether undreamt of.

We need not dwell here upon well-known systems for the transmission of power which are obviously specially applicable to comparatively short distances within a building or factory, such, for instance, as steam or air under pressure conveyed from a boiler or compressor by means of hollow conductors or pipes to steam or air engines, nor to the transmission of power by means either of water pressure conveyed in a similar manner, or by mechanical connections such as running belts and shafting, although quick running ropes have been used on the Continent for the conveyance of power through considerable distances from one part of a town to another, while hydraulic transmission has, as is well known, had most extensive application. All these systems have inherent drawbacks to their practical extension, beyond what, from our present point of view, we must term comparatively narrow limits. From the moment, however, when Œrsted, in the year 1819, made his brilliant discovery of the connection between magnetism and electricity, which was so splendidly developed by the researches of Arago and Ampère, and a few years later by those of Faraday, and when it became generally known that the transmission of a voltaic current through an insulated wire, wound helically around a bar of soft iron, converted that bar into a magnet, and that on the cessation or interruption of that voltaic current the iron was restored to its normal or unmagnetized condition, a vista was opened for inventors into an altogether new and fertile field for discovery. For many years the opinion held its ground that electricity was on the eve of supplanting all other natural forces, not only for motive power, but for many possible and impossible things besides, and the records of the patent offices of the various capitals of Europe and America prove that they were inundated with inventions for the conversion of electricity into motive power for driving factories and mills, drawing along carriages and railway trains, propelling ships at impossible and incredible speeds, and doing anything and everything that steam, and water, and animal power and all combined had ever done before. Notwithstanding this, the old forms of mechani-

cal power held their own, for it had been lost sight of, with that comforting one-sidedness which is the characteristic of so many enthusiasts and inventors, that until the consumption of the materials in the battery, by which the electricity was generated, could favorably compare in economy with that of coal in the steam boiler to produce the same mechanical results, there could be no sort of commercial field for electrical motors. In the midst of all this came the discovery and subsequent development of magneto-electricity which has culminated in the modern dynamo-electric machines, to which so much attention has been called during the last two years by the progress of the electric light; but, as all such apparatus requires motive power to drive, it obviously cannot take the place of the older forms of motors, in cases where the power is near the work, for it is clearly more economical to drive machinery direct from the original source of power than through the intervention of a series of conversions and reconversions into other forms of force; and, even within distances comprised within a single building or factory, it has up to the present time been only in very special cases that electrical transmission can compare in economy with that of belts and shafting.

When, however, the distance of the work to be done is at a greater distance from the available source of energy than that through which mechanical power can be advantageously transmitted by mechanical means, then the value of electrical transmission becomes apparent, and rapidly increases with the increase of distance by which other methods of transmission are rendered more and more impossible. It is a well-known fact that all dynamo-electric generators are perfectly reversible, that is to say, if the terminals of one machine be connected to those of a second machine in action, or with a voltaic battery, it becomes an electro-magnetic engine, and is driven round under the influence of the mutual action going on between the current transmitted through its armature and the magnetic field of its electro-magnets, and the direction of rotation of the second or driven machine (assuming that the two machines are similar in construction) is the reverse of that by which the current is produced. Upon this fact as a foundation is built the whole superstructure of the transmission of power to a distance by means of electricity. From the driving of a magnetic engine by a battery to driving it by the current from a magneto or dynamo-electric machine was a step too obvious for any one to claim it as an invention, but we believe it is a fact that the first public exhibition of the transmission of mechanical power from one dynamo-electric machine to another, through a length of conducting cable, was in the year 1873 at the Vienna exhibition, forming one of the objects of interest exhibited by the Société Gramme; and the public had an opportunity of seeing a Dumont centrifugal pump lifting water, which pump was kept in rotation by a Gramme machine, which was in its turn driven by the current from a second Gramme machine, to which it was connected by wires nearly three-quarters of a mile long; and we ourselves saw in August of the following year the whole of the lathes, tools, and other machinery in M. Gramme's factory in Paris driven by connecting one of his small lighting machines by means of a belt to the shafting, from which the steam engine was disconnected, which machine acting as a magnetic engine was driven at a speed of 815 revolutions per minute by a derived circuit from one of his large machines, which was producing at the same time on a second circuit a light of 2,400 candles; thus, during this experiment, the machinery of the workshop was both driven and illuminated by electric currents generated by the same machine. At the Philapelphia exhibition and also at the Loan Collection of Scientific Apparatus in London, both of which were held in the year 1876, experimental illustrations were also given of the driving of one Gramme machine by the current produced by another.

During part of this time, however, a highly interesting and instructive series of experiments were being conducted by Messrs. Siemens Brothers, the results of which are to a considerable extent recorded in the very able paper on dynamo-electric apparatus read before the Institution of Civil Engineers in January, 1878, by Dr. Higgs and Mr. Brittle, but the vast commercial import-

ance of the whole question of the electrical transmission of power was pointed out some ten months previous to the reading of that paper, by Dr. Siemens, in an essay which has since become historical, and which formed his presidential address to the Iron and Steel Institute, at their meeting which was held in London in the spring of the year 1877. In speaking of the possible exhaustion of the coalfields of the world at some remote period of its history Dr. Siemens called attention to other great forces of nature which might, when the time came, take the place of coal, and, in many places, supplement it even now. He reminded his hearers of the vast stores of potential energy running to waste in every part of the world in the unutilized power of its waterfalls, and drew attention to the fact that one of the falls of Niagara by itself represented a force of nearly 17,000,000 horse power, which, produced by steam engines consuming 4 lbs. of coal per horse power per hour, would involve an aggregate consumption of nearly 270,000,000 tons of coal per annum, and Dr. Siemens showed that by means of suitably arranged turbines and other hydraulic machinery, a large amount of this power might be utilized for the driving of powerful dynamo-electric machines which, by transmitting electric currents through metallic conductors to other and similar machines which would act as electro-magnetic engines, motive power might be conveyed through distances of many miles to work at a number of distant stations machinery employed in the industries of their several districts; and he estimated at that time that a copper wire or rod three inches in diameter would be capable of conveying 1,000 horse power over a distance of 30 miles; or if the currents were utilized for the production of the electric light, a moderately sized town might be illuminated at the same distance from the original source of power.

There is in connection with the transmission of power electrically by the driving of one dynamo-electric machine by the current from another, one very interesting and all-important fact which is inseparable from, because it forms part of, the principle of its action. We have seen that if a continuous current of electricity, from whatever external source, be transmitted through the coils of a dynamo-electric machine, the latter is caused to revolve in what may be called its reversed direction, and as the rotation of the armature of such a machine within the magnetic field of its electro-magnets produces an electric current, whose direction is determined by the direction of rotation of its armature with respect to the polarity of its magnets, it follows that the second machine in being driven generates a current of its own which is opposite in direction to the original current by which it is itself driven, and as the currents from both machines are generated in the same circuit it follows that the original current is reduced by an amount which is the difference of the strengths of the respective currents for the two machines. When the second machine is at rest the current from the driving machine is at its maximum, no back or opposing current being generated, but at the same time no mechanical power is transmitted, and it is found by experiment, as a little consideration of the problem would lead one to predict, that the maximum work is obtained from the second machine when its current has reduced the current from the first machine to one-half of its original strength, and thus with two equal machines connected together for the transmission of power about one-half of the work put into the first machine is reclaimable from the second.

As by Ohm's law, the strength of an electric current varies directly with the electro-motive force of its generator, and inversely with the electrical resistance of the conductor through which it is transmitted, it follows that with a constant electro-motive force (which in dynamo-electric machines is obtained when the speed of rotation is uniform) the strength of the current depends exclusively upon the resistance of the circuit which, other things being equal, is inversely proportional to the area of its cross section (which in round conductors is equal to the square of its diameter), and is directly proportional to its length. From these considerations, taken in connection with the fact that the greatest efficiency from a dynamo-electric machine is obtained when the external resistance of the circuit does not exceed the internal resistance of the machine, it follows that

if a machine be transmitting power to a second machine through a certain distance, and it be desired to double that distance, a conductor would have to be employed of double the length, which would have twice the resistance; and in order to reduce the resistance of the circuit to what it was before, so as to balance that of the machine, a second conductor would have to be employed, or else a single wire of double the sectional area of the first, and this would multiply its weight, and therefore its cost four times, which would appear at first sight to be prohibitive of the extension of transmission circuits to great distances, seeing that the cost and the weight of the conductor for each circuit increases as the square of the distance transmit ted; but Dr. Siemens was the first to point out a redeeming qualification, which is probably the most important, as it is at first sight the most startling, feature in connection with this most interesting subject, viz., that as at the double distance with the double conductor there is twice the area to be dealt with, a second generator can be set to work, and two machines instead of one can be driven at the double distance; and he showed from that "that it was no dearer to transmit electro-motive force to the greater than to the smaller distance, as regarded weight and cost of conductor, a result," he added, "which seemed startling, but which he nevertheless ventured to put forward with considerable confidence."

Passing from theoretical considerations to practical applications, we may remind our readers that at the conversazione given at South Kensington by the Institution of Civil Engineers and by the Society of Telegraph Engineers, a pair of Simens' machines attached to a Brotherhood three-cylinder engine, such as was figured and described in these columns a few weeks ago, were driven by the current from one of the Siemens machines in the Albert Hall through a conducting cable over half a mile in length. One of the earliest practical applications of the electrical transmission of motive power to industrial purposes was made by M. Cadiat, who in the workshops of the Société du Val d'Osne, in Paris, drove a Gramme machine such as is employed for electro-plating purposes by the current from a distant electric lighting machine transmitted through two wires three millimeters in diameter, and nearly 500 feet long. In the following year MM. Chrétien et Felix established in connection with a sugar factory at Sermaize an electrical hoisting apparatus or crane, by which beet roots were unloaded from vessels lying alongside the quay, situated more than 100 metres (328 feet) from the factory from which the apparatus was driven, and by this apparatus, during one season alone, 400 tons of beet root were discharged from boats arriving at the port of Sermaize. The success which attended this installation was so great that the inventors were induced to construct electrical implements for agricultural purposes, to take the place of the steam-plowing engines generally employed. The apparatus, which is very simple, consists of two electric hauling engines, similar in the hauling apparatus to that usually employed in steam power, but differing in the motive power, which is obtained by two Gramme machines, which can be coupled to or disconnected from the winding drum by throwing into or out of action frictional gearing, by which the revolving spindles of the two Gramme machines driven from a distant engine are connected to the drums below the apparatus, which by means of a wire rope draws backwards and forwards the multiple balance plow, as in ordinary steam cultivation. In the installation at Sermaize, the motor machines were driven at a speed of 1,600 revolutions per minute, and those on the hauling apparatus at 800 revolutions; the advancing speed of the plow was from 160 feet to 265 feet per minute, and by this apparatus an area of 215 square feet was plowed in the same time.

By far the most important installation, however, of the application of the electrical transmission of motive power for agricultural operations has recently been established upon the estate of M. Menier, whose world-wide reputation rests upon a three-fold basis from the fact that he is at once a very prominent member of an extreme party of the French Chamber of Deputies, the proprietor of the most important chocolate manufactories in the world, and an eminent electrician and electrical cable manufacturer. For some weeks past a series of important agricul-

tural experiments have been carried on by M. Menier, by which the power of water, which is abundant on his Noisiel estate, has been applied to plowing and other agricultural operations through the intervention of electricity, and we publish on page 412 of our present issue a drawing of the special form of a Gramme dynamo-electric machine employed by him in their installation both for generating the electric currents in the first instance, and reconverting them into mechanical power at the distant station.

This special form of apparatus consists, as is shown in the drawings, of a Gramme armature about 18 inches in diameter, and the same in depth, which is capable of revolving on a horizontal spindle within the magnetic field produced by eight flat electro-magnets arranged in pairs around the armature, each pair being united by a pole-piece common to both, and these four pole-pieces are fixed around the armature at equal angular distances apart, and following one another with alternating polarity, so that the poles presented to opposite ends of the same diameter of the ring are (unlike the arrangement in the ordinary Gramme machine) of the same polarity, the alternating poles being separated by an angular distance of 90° instead of 180°. By this arrangement a very powerful magnetic field is maintained, and the impelling forces in the apparatus are more uniformly distributed around the shaft to be driven. As there are four poles there are of course four neutral points in the circuit of the armature, and, therefore, there are four distributing brushes, by which the currents transmitted by the machines at the distant station, after traversing the four pairs of magnets are conducted into the circuit of the armature at the proper positions to insure their maximum effect.

With two hauling engines driven by four machines of this description M. Menier proposes to perform all the plowing and other agricultural operations on his farm at Noisiel, of 3,000 acres, and the currents by which they are worked will be transmitted by four similar machines driven by turbines which are already at the works. The power to be transmitted by the apparatus is about 36 horse power, *i. e.*, 18 horse power per winding engine, and by means of a wire rope a Fowler plow with six shares is drawn backwards and forwards, plowing six furrows at a time at a speed of nearly 200 feet per minute.

We understand that it is the intention of M. Menier to extend this electrical system of cultivation to all the farms on his estate, one of which is situated at no less distance than three miles from the driving station, the motive power at which is derived from a waterfall on the Marne, which is at the present moment actually being used for driving eight machines by which the workshops of his chocolate factory are illuminated.

We shall on a future occasion refer again to these interesting installations, and shall describe more in detail some of the more important of the apparatus employed.

NOTES ON IRONWORK.*

From "The Builder."

The branch of science which enables the engineer to determine the theoretical amount of strain in the members of any proposed structure may be said to appeal directly to ordinary intelligence, and to be on the whole simple. The science, however, depends upon data and conditions the exact influence of which can never be determined in actual practice. It is proposed, therefore, in this paper to consider briefly some of the practical questions which affect theoretical deductions, and the design, efficiency, and economy of ironwork structures generally. The precise conditions under which ironwork will be constructed and worked being indeterminable, it becomes necessary, among other matters, to have some knowledge of workshop practice, or routine, in order to determine the proper limits and importance to assign to theoretical result.

In taking out strains, it is usually

* From a paper by Mr. Graham Smith, C. E., read at the meeting of the Association of Municipal and Sanitary Engineers and Surveyors,

assumed that each member has a normal length whatever the amount of strain to which it is subjected, and that its conditions are the same as they would be were it free to turn in a plane about its extremities. Both of these assumptions are, to a certain extent, erroneous. So far from any bar having a normal length, that is, being perfectly rigid, it may be taken for granted that directly any piece of iron is subjected to a tensile or compressive strain, its length is varied accordingly. Likewise, no member of any structure is perfectly free to turn in a plane about its extremities; were it so, each junction would have to be made with an absolutely frictionless pin. In English practice, junctions are frequent ly made with innumerable small rivets, which render them to all intents and purposes rigid. In America, however, pin connections are employed to a very large extent, and undoubtedly, with pins and eyes properly proportioned, efficient joints may be made, and with simple arrangements of parts, theory be more closely approached than with our complicated systems with riveted joints.

Variations in the temperature of the atmosphere likewise materially affect the strains in iron structures. When constructing an iron bridge, a camber is given to it, so that when loaded it may assume a straight line, instead of exhibiting signs of apparent weakness by sagging. While testing the bridge, it is usual to measure the camber as the load is put on, and it is not uncommon to find that on a warm day the camber is greater than it was the evening before, notwithstanding that a larger amount of load has been put upon it. This anomaly is due simply to the sun warming up the top flanges, and causing them to extend, whilst the bottom flanges have not extended to a similar extent, owing to being protected from the sun by a platform or the load upon the bridge. It has been ascertained that a variation of temperature in iron of 15° Fahr. will produce the same effect as one ton actual load per square inch; therefore, a change of 82.5° Fahr. will produce the same effect as 5.5 tons per square inch actual load, which is greater than the amount of strain supposed to be put upon any bar when under its full working load. Now, although the difference between the extremes of temperature in this country may be estimated at 82.5° Fahr., the extreme temperatures only act during a short portion of each twenty-four hours; and so, owing to the mass of iron and other circumstances, the temperature of the structure is seldom the same as that of the atmosphere, consequently the iron is not affected to the full extent just mentioned. There are, of course, many positions which will at once suggest themselves where the temperature is tolerably uniform throughout the year, and where accordingly no provision need be made for expansion and contraction due to changes of temperature. In exposed positions in this country, an allowance of seven-sixteenths of an inch in each 100 feet should be made if it is wished to eliminate strains which it has been shown may be of considerable amount. Edwin Clark has placed it on record that half an hour's sunshine has more effect on the tubes of the Britannia Bridge than the heaviest rolling loads or the most violent storms.

Questions of the foregoing nature having been considered, and the strains upon the various members of the proposed structure having been determined within reasonable limits, it becomes necessary to arrange the material to meet them. It is in doing this properly and economically that the art of designing ironwork consists. In all designs every endeavor should be made to employ iron of such dimensions and weights that it may be easily procured in the open market, and require only such workmanship as can be cheaply and readily performed. By attention to these points economy will be more surely attained than by saving in the weight of iron, which may be effected by adhering more closely to theoretical refinements. As an instance of this it may be stated that the actual weight of a plate girder is always very much in excess of its theoretical weight, and it is rarely the lightest form of girder which it is possible to design to carry a load; it is yet generally the most economical type to adopt for small spans, owing to the uniformity of its parts and the simplicity of its manufacture. While mentioning plate-girders, it may be well to state that although the theoretical economical depth of all girders depends upon their

description, the loads to be carried, and a variety of other circumstances, the depth of a plate-girder is often fixed by one consideration alone, and that of a practical nature quite beyond the control of the designer. It is simply the fact that plates cannot be rolled at ordinary rates over 4 feet six inches in width, so that the maximum depth of ordinary plate-girders is fixed at 4 feet 6 inches. If this depth is exceeded, it becomes necessary to plate the web vertically, which will enhance the cost of the work to an extent exceeding the saving likely to result from conforming more nearly to any greater depth which theory might dictate. In arranging the flanges, although theoretically the section of metal should be reduced at certain points, it is generally desirable, when a limited number of girders are to be made from one design, to keep the plates as nearly uniform in thickness as possible, rather than to vary their thickness so as to approach more closely to the amount of metal required to meet the strain. However, where a large number of girders are to be constructed from the same design, the plates may be varied in thickness without increasing in any way the cost of the work, as the plates can be ordered in batches from the rolling-mills and relegated to their respective girders in the manufacturer's yards.

At one time much of the iron employed for girder and bridge building came from Staffordshire; consequently specifications were prepared in such a manner that iron from this district might comply with their stipulations. These specifications have been copied and re-copied even up to the present time, notwithstanding that Staffordshire iron is now rarely put into ordinary work, for the reason that the sizes of the iron supplied from this district are small when compared with those from the north country. This is owing to the Staffordshire mills working with plant which was put down many years since, whilst the ironworks in the Cleveland district are provided with more modern machinery and improved appliances. A South Staffordshire plate to cost the ordinary market rate must not be over 4 cwt. in weight, 15 feet in length, and 4 feet in breadth, and about 30 superficial feet in area; whereas Cleveland plates can be procured without additional cost up to 21 feet in length, 4 feet 6 inches in width, and 12 cwt. in weight, providing the area does not exceed 56 superficial feet. Although plates from the latter district may be obtained possessing as great a tensile strength both with and across the fibre as those from Staffordshire, they are not as a rule equal to the latter in toughness. Extra care should therefore be taken to test and thoroughly ascertain the quality of the iron, as it is sometimes very brittle. No attention whatever should be paid to "brand," as it is no criterion by which to judge of the qualities of iron usually employed for the construction of ordinary ironwork. A very fair specification for girder iron is 20 tons per square inch and six per cent. elongation with the fibre; 18 tons per square inch and three per cent. elongation across the fiber for plates; 22 tons per square inch and nine per cent. elongation for L and T's; and 24 tons per square inch and 15 per cent. elongation for rods and bars. These elongations ought to be taken on a testing section of uniform width for a length of $6\frac{1}{4}$ inches. In a length of $6\frac{1}{4}$ inches there are one hundred sixteenths of an inch, so that each $\frac{1}{16}$ elongation after testing represents one per cent. In preparing all samples for testing they should be drilled out of the plate angle or bar, and be either chipped or slotted to the required dimensions, and all tool marks carefully filed out, and the parallel portions should run in with curves of large radii to the portions through which the pin-holes are drilled. In the event of there being the slightest shoulder at either of these points, it will have the same effect as a nick in the iron, which will generally render worthless the test for both tensile strength and elongation. With a little experience the quality of a plate may be determined to some extent by breaking the corner off over an anvil, and by inspecting the punchings from the plates. If the iron is brittle and untrustworthy, the punchings will show cracks in all directions if the punch be working as ordinarily with a little clearance, whereas if the iron is good and reliable slight cracks only will be perceptible—all running in the direction of the fiber. Whilst these workshop tests can be carried out in the manufacturer's

yard by the inspector during the progress of the work, all tests requiring to be made with hydraulic presses or steel-yards, should be conducted by independent authorities, such as Mr. Kirkaldy. After the material has been tested and passed, and the structure put together, it becomes necessary to apply a proof-load, which consists of gradually placing on the structure a weight somewhat exceeding its working load. This is requisite in order to ascertain if the workmanship is up to the proper standard. It must, however, be always remembered that a proof-load is no test of the strength of the structure or the quality of the material. If the iron is hard and brittle it will give less than a material of more desirable quality, and the structure will apparently be stronger, but it is needless to state that such is not the case. Again, any part may be on the point of breaking, and yet not yield sufficiently to materially alter the deflection. Likewise, although a structure may stand the application of a proof-load at the time of testing, it does not follow that it will stand repeated applications of loads of even less amount than the proof-load. Fairbairn's experiments, carried out many years back, demonstrated this fact. He found that when the strain on the iron of a beam was between six and seven tons per square inch, the beam sustained an unlimited number of applications of the load producing this strain; but when the load was increased so as to put a strain of from eight to nine tons per square inch on the iron, the beam failed with comparatively few applications of the load.

ON THE STRENGTH AND ELASTICITY OF MATERIALS.

By WM. JAMES MILLAR, Secretary to the Institution of Engineers and Shipbuilders in Scotland.

From the Proceedings of the Institution of Civil Engineers.

THE object of the author is briefly to describe some experiments upon the strength and elasticity of materials. During the course of his practice he has made numerous tests of cast iron bars, the results of which are given in

TABLE I.

Dimensions of Bars.			Number of Tests.	Average Ultimate Strength.	Average Ultimate Deflection.	Average Modulus of Rupture.	Remarks.
Span.	Breadth.	Depth.					
Inches.	Inches.	Inches.	Bars.	Lbs.	Inch.	Lbs. per Square inch.	
36	1	2	1,344	3,740	.400	50,490	The bars were loaded at the center.
36	1	1	50	801	.583	43,254	
36	2	1	1	1,763	.843	47,601	
..	..	..	Links. 66	21,122	..	..	

From the above results the following constants and rules have been determined:

$$W=\frac{25\times b\,d^2}{S};\quad D=\frac{W\times S^3}{b\,d^3}.0036;$$

$$T=\frac{.44\times W\times S}{bd^2};\quad W=\frac{T\times bd^2}{.44\times S}$$

when W = ultimate load in cwt. at the center of the bar; S = span in feet; b = breadth in inches; d = depth in inches; D = deflection in inches; and T = tenacity in tons per square inch.

It was found that when the bar broke at, or close to, the center, the fracture was straight; but when fracture occurred at points removed from the center, the form was curved: hence the form of fracture invariably shows the position of fracture. The author has also proved by experiment that this law applies to bars of steel, glass and sealing wax. These curved fractures all pointed towards the point of application of the load, the curve increasing with the distance of fracture from the center of the bar. In no case was a wood-shaped piece forced

out of the compressed side of the bar; the fractured parts always fitted together. Flakey or lumpy fractures with a purplish gray color indicated strength. Dull smooth surfaces, crumbling to the touch, indicated weakness; a sparkling metallic look indicated soft iron. The breaking of the outer surface, or skin, did not materially affect the strength.

When bars had been subjected to a high load, it was found in many cases that, on a second application, they broke below the first applied load. Vibration, obtained by tapping the bar when loaded, had also the effect of causing rupture.

Some exceptionally strong bars showed a decrease of deflection with increase of load, as will be seen by

TABLE II.

Average of fourteen bars unbroken.....Loads, lbs.	3,360	3,920	4,480
Deflection*.....Inch	.327	.317	.313
Single experiment.....Loads, lbs.	3,360	3,920	4,480
Deflection.....Inch	.380	.370	.350
Set..... "	.008	.002	.000

Experiments to determine the law of set showed that, at high loads, the set decreased for additional loads. There was also a decrease of set for repeated applications of the same load; but when starting with small loads, and gradually rising until fracture took place, the set appeared to increase, then remain steady, and afterwards decrease. Some of these results are shown in

TABLE III.

Average of ten bars unbroken.....Loads, lbs.	3,360	3,920	4,480
Deflection.....Inch	.341	.367	.388
Set..... "	.026	.014	.008

TABLE IV.

Load applied, 2,800 lbs.	Bar No. 1.		Bar No. 2.		Bar No. 3.		Bar No. 4.	
	Deflection.	Set.	Deflection.	Set.	Deflection.	Set.	Deflection.	Set.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
1st application of load.	.302	.021	.336	.020	.290	.012	.298	.015
2d " "	.282	.003	.317	.005	.290	.005	.296	.002
3d " "	.279	.001	.310	.001	.286	.003	.285	.002
4th " "	.278	.000	.312	.000	.282	.000	.281	.000
5th " "	.276	.002	.313	.000	..	..	..	..
6th " "	.273	.001	.315	.000	..	..	..	..
	Finally broke about 3,500 lbs. Deflection, .403.		Finally broke at 4,270 lbs. Deflection, .518.		Finally broke at 4,330 lbs. Deflection, .455.		Finally broke at 3,760 lbs. Deflection, .395.	

Often when near the breaking point a slight increase of deflection was observed to take place suddenly. From various observations this change appeared to occur at loads of about 97 per cent. of the ultimate strength.

In experiments to determine the relative strengths of hot-run and dull-run metal, the bars were cast from the same metal, the first being cast as hot as possible, and the others from metal which had been allowed to cool until it would only

*All deflections mentioned in the tables are those for corresponding loads. The deflection for each experiment being noted, a re-adjustment of the deflection circle to zero was made, and the experiment repeated.

just flow into the mould, with the result shown by Table V.

It will be observed that the dull-run metal gives the highest breaking strength, but the deflection is less than with the hot-run metal.

From experiments upon the cooling of bars, it was found that bars cooled in the mould gave higher results than those cooled in the air; thus:

The average of nine bars cooled in the mould was 4,206 lbs. with a deflection of 0.404 inch.

The average of ten bars cooled in the air was 4,009 lbs., with a deflection of 0.396 inch.

So far as the author has been able to determine, the action of severe frost on bars does not affect their strength.

TABLE V.

	Hot Metal.		Dull Metal.	
	Ultimate Strength.	Ultimate Deflection.	Ultimate Strength.	Ultimate Deflection.
Average of ten bars.....	lbs. 3,524	Inch. .402	lbs. 3,619	Inch. .371

The results of experiments, made at the instance of Mr. David Rowan, M. Inst. C.E., and recorded by the author, on bars of forged and rolled iron, subjected to bending stress in a similar manner to the cast iron bars, but with the application of the same load, are given in Table VI.

These experiments were repeated, with increasing loads, when the results arrived at are shown in Table VII.

TABLE VI.

Load applied, 37 cwt. Forged Bar.	Deflection.	Set.	Load applied, 37 cwt. Rolled Bar.	Deflection.	Set.
Span 36 inches; breadth $\frac{17}{16}$ inch; depth 2 inches.	Inch.	Inch.	Span 36 inches; breadth 1 inch; depth 2 inches.	Inch.	Inch.
1st application of load..	.230	.031	1st application of load.	.700 rising to .870	.535
2nd " " ..	.200	..			
3rd " " ..	.180	.062			

TABLE VII.

Forged bar.....cwt.	32	34	35	37	Left in machine at 37 cwt. for seventeen hours. Deflection .180, and set .093 inch.
Loads.....lbs.	3,584	3,808	3,920	4,144	
Deflection.....inch.	.180	.175	.180	.192	
Set..... "	None.	..	..	None.	
Rolled bar.....cwt.	26	26	28	30	32
Loads.....lbs.	2,912	2,912	3,136	3,360	3,584
Deflection.....inch.	.150	.150	.160	.170	.190, rising to .235 inch.
Set..... "	None.	None.	None.	..	Set .062 inch.

The critical points in these bars appear to lie about 36 and 30 cwt. Taking these loads as the limit of elasticity, the modulus of longitudinal strength or tenacity would be, $f = \frac{6 \times W \times S}{4 \times bd^2}$, where W = load in lbs., S = span in inches, b and d being the breadth and depth in

inches. Substituting the values as given for the above bars, then—

in the forged bar,

$$f=\frac{6\times3{,}920\times36}{4\times\frac{11}{16}\times2^2}=49{,}807 \text{ lbs.},$$

and

in the roll bar,

$$f=\frac{6\times3{,}360\times36}{4\times1\times2^2}=45{,}360 \text{ lbs.}$$

Taking the formula, $E=\frac{W\times8^3}{4Dbd^3}$, as the modulus of elasticity, then, when W= 3,920 lbs.,

for the forged bar,

$$E=\frac{3{,}920\times36^3}{4\times.180\times\frac{11}{16}\times8}=29{,}880{,}000 \text{ lbs.},$$

and

for the rolled bar,

$$E=\frac{3{,}360\times36^3}{4\times.170\times1\times8}=28{,}800{,}000 \text{ lbs.}$$

In the above formula D is the deflection in inches.

If the cast-iron bars be taken at loads where set disappears, and the whole deflection becomes elastic, the modulus of elasticity will vary from 14,500,000 to 18,600,000 lbs.

The author inclines to the belief that the so-called "set," observed in cast iron bars, is really due to the relief of the particles from strain produced in cooling, and is not similar to the permanent set observed in wrought iron and steel. From the results of the experiments on the cast-iron bars the elastic deflection appears to vary proportionally with the load.

THE CHORDEL: AND ITS APPLICATION TO THE GENERAL SECTION OF AN ANGLE.

By J. BRUEN MILLER.

Written for VAN NOSTRAND'S MAGAZINE.

A Chordel is the path of a point in a plane, moving in such a manner that if, with a fixed point in the plane as a center, circumferences of circles be described, the arcs of these circumferences included between the path of the generating point and a fixed line in the plane, will each of them subtend a given portion of a right line, as a chord, the same number of times.

The given portion of a right line is called the ELEMENT; the fixed point in the plane, the FOCUS; and the fixed line the DIRECTRIX.

Chordels are classified:

1st.—According to the number of times the element is subtended as a chord; whether once, twice, n times, &c.

2d.—According to the nature of the directrix; whether a straight or curved line, an hyperbola, ellipse, etc.

3d.—According to the position of the focus, whether on the directrix, or at a certain distance from it.

A chordel in which the element is subtended n times, as a chord, whose directrix is a right line, and whose focus is on the directrix, is called—

A chordel of n *elements, and rectilinear and focal directrix.*

PROBLEM I.

TO CONSTRUCT A CHORDEL OF n ELEMENTS AND RECTILINEAR AND FOCAL DIRECTRIX.

Let n equal any number, as 2, and let AB, (Fig. 1, p. 207) be any given right line, CD, any definite portion of a right line, and F, any point on AB. With AB as the directrix, CD, the element, and F, the focus, it is required to construct a chordel of two elements. With F as a center, describe the arcs GEH, G′E′H′, G″E″H″, etc., and at the points E, E′, E″, etc., where these arcs cut AB, lay off on these arcs in both directions, the chords Eh, hH; Eg, gG; E′h', h'H′; E′g', g'G′; E″h'', h''H″; E″g'', g''G″, etc., each equal to the element, CD, and to each other. The points H, G, H′, G′, H″, G″, etc., are points in the required chordel, since the arcs described from F as a center, and intercepted between these points

and AB each subtend CD as a chord, twice; in the same manner, an indefinite number of points may be found and the chordel XPCY constructed. The same process may be employed when n equals any other number.

Corollary 1.—It will be seen from the figure that the chordel is a curve, extending indefinitely in the directions PX and PY; that it is *symmetrical* in reference to the directrix, if the focus be upon it, and also, if the same process be carried on to the right of F, a precisely similar figure will be the result, and the curve will have two branches.

Corollary 2.—The points h, g, h', g', h'', g'', etc., are points in a chordel of *one element*, whose element is CD, directrix AB, and focus F. Hence the process given above may be used in the construction of any species of chordel.

Corollary 3.—The point C, or the *limit* of the curve, may be found by an analysis; for it must be at the intersection of the directrix with the circumference of a circle whose center is the focus F, and which must contain CD as a chord twice; or the circumference of the circle CMDN, whose diameter is CD. FC, the radius of CMDN is therefore

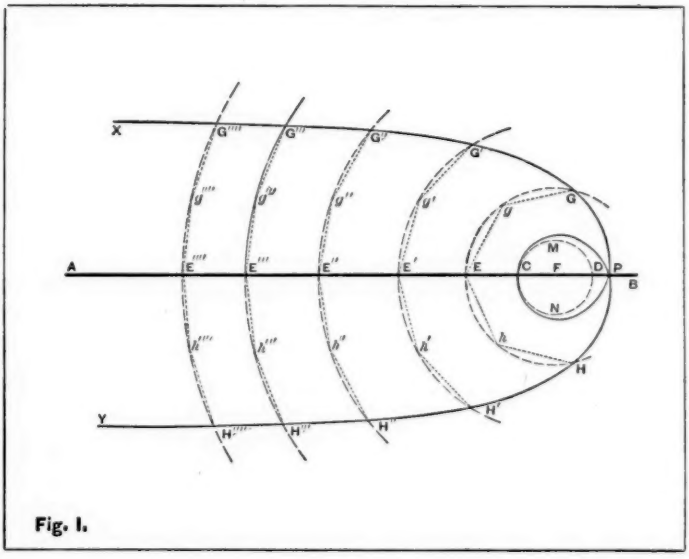

Fig. I.

one-half of CD, and the limit of the chordel XPCY is therefore a point C, on the directrix AB, at a distance from the focus equal to one-half the element. By a similar mode of reasoning, the point P, where the curve again cuts the directrix, may be found, and in general, all points of chordels common to the directrix and the curve itself.

It follows from what has been demonstrated that:

The chordel is a plane curve, generated by one of the points of intersection of a series of right lines which shall intersect in such a manner that each line will contain two points of intersection at a given distance apart, the lines moving so that they shall constantly be in the same plane, their points of intersection equally distant from a fixed point in the plane, and one of their points of intersection constantly remaining on a fixed line in the plane.

It is evident from this definition, that any chordel may be constructed *mechanically*, as follows:

Take n rods of equal length, and hinge their extremities; to these extremities attach cords of equal length, and fasten them together at the ends. Now upon any plane surface lay another

rod whose edge shall be of the nature of the directrix of the required chordel; upon a certain point in this plane insert a pin or tack around which the cords may pass; lay the hinged rods on the plane, pass the cords around the pin, and move them together in the plane, so that the cords are constantly taut and the end of the first rod pressed against the fixed rod in the plane. Any one of these hinged extremities will describe a chordel, of which the length of the hinged rods is the element, the rod in the plane the directrix, and the pin or tack the focus. If the fixed rod has a straight edge, the pin inserted against this edge, and a pencil point attached to the extremity of the nth hinged rod, this pencil point will describe a chordel of n elements and rectilinear and focal directrix.

DEFINITIONS.

Any portion of a chordel, cut by the directrix is *segment* of that chordel. Thus, PX, PY, etc. (Fig. 1), are segments of the chordel XPCY. PX is *reverse* to PY.

PROBLEM II.

TO DIVIDE AN ANGLE INTO n EQUAL PARTS.

Let ACB (Fig. 2) be any plane angle and let n equal any number, as 3. It is

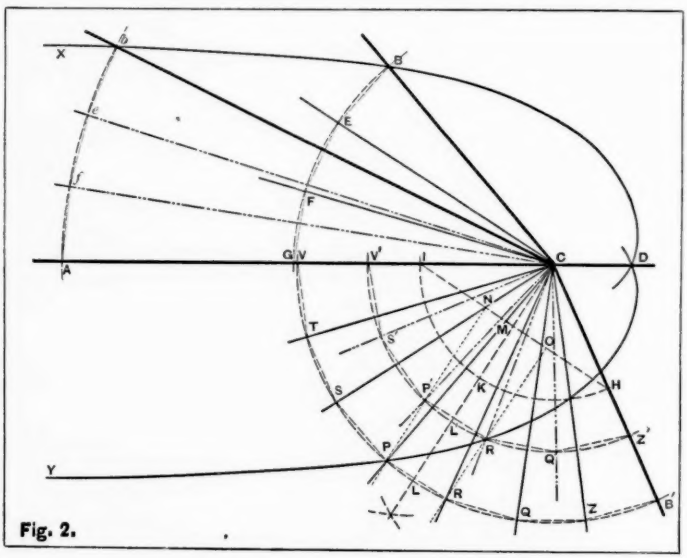

Fig. 2.

required to *trisect* the angle ACB. Prolong one of the sides of the angle, as AC, indefinitely, and lay off any convenient portion, as CD. Now with AC produced as a directrix, CD as the element, and C the vertex of the given angle, ACB, as the focus, construct a chordel of 3 elements. DX will be a segment of this chordel. Through the point B, where BC cuts DX, describe the arc BG from C as a center; then will BG measure the angle ACB. But from the nature of the curve of which DX is a segment, the arc BG subtends CD as a chord, three times. Therefore, laying off the chords GF, FE and EB, each equal to CD and to each other, the arcs GF, FE and EB will be equal to each other, and each to one-third the arc GB. Hence the angles GCF, FCE and ECB are each equal to one-third the angle ACB, and to each other, and the angle ACB is *trisected* as required. Had n been taken as equal to any other number, the same process could be employed.

Corollary 1.—*By means of the segment* DX, *any other angle may be trisected.* Thus the angles AC*f*, *f*C*e* and *e*C*b* are each equal to one-third the angle AC*b* and to each other. The same is obviously true of the *reverse segment* DY.

Corollary 2.—If $\frac{n-1}{2}$ be an *integral number*, or if n be an *odd number*, a shorter process may be employed. Thus, let n equal the odd number, 7, and let it be required to divide the angle ACB′ (Fig. 2) into seven equal parts. $\frac{n-1}{2}$ will equal 3. With AC produced as a directrix, C as a focus, and CD the element, construct a chordel of 3 elements. DY will be a segment of this chordel. With C as a center, and with any convenient radius, describe the arc HKI, measuring the angle ACB′. Draw the chord, HI of this arc, and bisect the angle ACB′ by the straight line CL. CL will, therefore, bisect the arc HKI, and its chord HI. From the point M, where CL bisects HI, lay off on HI, MN, and MO, equal to each other and each to one-half the element CD, and at the points N and O, erect NP, and OR, perpendicular to HI, and therefore parallel to each other. Through the point P, where NP cuts the segment DY, describe the arc B′LV with C as the center, and produce OR until it cuts B′LV at R. Since NP and OR are perpendicular to HI, they are parallel to the radius CL which bisects the chord HI, and since MN and MO are equal, the parallels NP and MO are equally distant from CL, whence the arcs RL and PL are equal. But since CL bisects the arc PR, or the sum of the equal arcs RL, and PL, the chord RP, subtending that arc is also bisected by CL, whence CL is perpendicular to RP, and therefore NP and OR are also perpendicular to RP. But since OR and NP are parallel, RP is equal to NO, and since OM and NM are equal to each other, and each to one-half the element CD, the sum of OM and NM or its equal, RP is equal to the element CD. The arc VP is equal to the arc B′R; for since CL bisects the whole arc, B′LV, and RL equals PL, the difference of B′L and RL, or the arc B′R, is equal to the difference of VL and PL, or VP. The arc VP subtends CD as a chord three times from the nature of the curve DY; therefore the arc B′R must also subtend CD as a chord three times; but PR, or the chord of the arc RLP, is equal to CD, whence the whole arc B′LV, measuring the angle ACB′, or the sum of the arcs B′R, RP, and PV must subtend CD as a chord seven times, and if from the extremities of these chords straight lines be drawn to C, the angles thus formed, B′CZ, ZCQ, QCR, RCP, PCS, SCT, and TCV, will be equal to each other, and each to one-seventh the whole angle ACB′. In like manner could any other angle be divided into seven equal parts by means of the segment DY or its reverse segment DX, and the same process of reasoning may also be employed when n equals any odd number.

Corollary 3. If through the point R′ where OR cuts the segment DY of a chordel of 3 elements, an arc be described measuring the angle ACB′, and CD be applied as a chord, the angle ACB′ may be divided into *five equal parts*. For, (Corollary 2), the arcs Z′R′, and V′P′ are equal to each other, and the chord R′P′ of the arc R′L′P′ is equal to CD, whence V′P′ subtends CD as a chord twice, as does Z′R′, and the whole arc Z′L′V′ subtends CD as a chord five times, whence the angles Z′CQ′, Q′CR′, R′CP′, P′CS′, and S′CV′, are equal to each other and each to one-fifth the whole angle ACB′. In like manner the fifth part of any angle could be found; and in general, if the chordel be one of $\frac{n-1}{1}$ elements, the $\frac{1}{n-2}$ *equal part.*

NOTE.

The discussion of the chordel has not been carried further than it may directly apply to the nth section of a plane angle, nor is the process employed above the only one by which a chordel may be used in accomplishing this result. Sufficient has been demonstrated, however, to show the simplest process, and also to show that by a chordel of $\frac{n-1}{2}$ elements and focal and rectilinear directrix, any plane angle may be divided into n, $n-2$, and $\frac{n-1}{2}$ equal parts without the use of any combinations to obtain these results. Of course, by combining, we may obtain the $\frac{1}{n^2}, \frac{1}{n^3}, \frac{1}{n(n-2)}$, etc. equal part, and the number of divisions may thus be increased. It may be claimed for the chordel, however, that it affords the only mathematical solution yet known to the GENERAL SECTION OF THE ANGLE.

ON THE ACTION OF JETS OF WATER ON CURVED VANES.

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1. In considering the effect of jets of water on vanes, Weisbach and Rankine make use of different methods; the latter first finds an expression for the impulsive force of the jet against the vane, and thence the work done per second, if the vane is moving with a uniform velocity; while the former, by comparing the final, with the initial absolute kinetic energy of the mass of water passing over the vane per second, derives an expression for the energy transmitted to the vane per second, and from that passes to the impulsive force. Weisbach's method requires the vane to be in motion, while both methods employ, at the very outset, the quantity of water delivered over the vane per second. It has occurred to the writer, therefore, that, since the pressure against the vane has a finite value at any instant of time, it would be analytically much more direct and intelligible, to determine the total force in any assigned direction, by summing up the components, in that direction, of the pressures exerted against the vane by all elements of that portion of the stream which is *at that instant* in contact with the vane. The following discussions, relating to vanes and to one form of turbine, have been developed in accordance with this view:

The investigation of the circumstances of motion of a particle moving without friction in a groove on a rotating disk, (especially its pressure against the side of the groove) as preliminary to the problem of the turbine, will, it is hoped, be found interesting on its own account.

2. As a fundamental equation we must use the proportion $\frac{P}{G}=\frac{p}{g}$; *i. e.*, the force P, which, at any instant, is changing, at the rate p, that component of a body's velocity which lies in the direction of the force, bears to the attraction of gravity on that body, G, the same ratio as that rate of change (or acceleration), p, does to the rate of change of the velocity of a free fall.

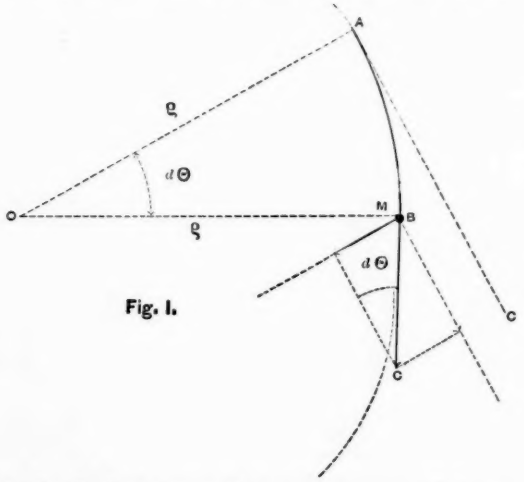


Fig. I.

Hence $P=\frac{G}{g}p=Mp$, M denoting the mass or amount of matter in the body.

3. Hence, Fig. 1, if a particle whose mass is M, moving with a velocity c, is deviated from the straight tangential path AC, into the curved path AB, by the smooth curved guide whose radius of curvature at A is ρ, the pressure of

* Written March, 1879.

the guide against M (or the re acting pressure of M against the guide) is $P = M\frac{c \sin d\theta}{dt}$, since $c \sin d\theta$ is the change of velocity in the direction Ao in the time dt; *i. e.*, $P = Mc\frac{d\theta}{dt}$, putting $\sin d\theta = d\theta$ since we are only concerned with the pressure at a single point of the curve. But $AM = \rho d\theta = c\,dt$, or $\frac{d\theta}{dt} = \frac{c}{\rho}$; $\therefore P = \frac{Mc^2}{\rho}$ the ordinary form for a deviating or centripetal force. If the guide is itself moving, each of its points with the *same* parallel velocity, the form of P remains the same, but c then denotes the velocity of M *relatively* to the guide.

4. Apply this to the case of a stream of water impinging *tangentially* upon a smooth curved vane, which is constrained to move in the direction of the stream, but at a less velocity v.

Parallel borders not shown in the figure (Fig. 2) may be supposed to keep the stream at right angles to the elements of the cylindrical surface.

Let F = cross-section of the stream, which can be considered constant over the whole arc OB = s. From the preceding we know that an elementary mass

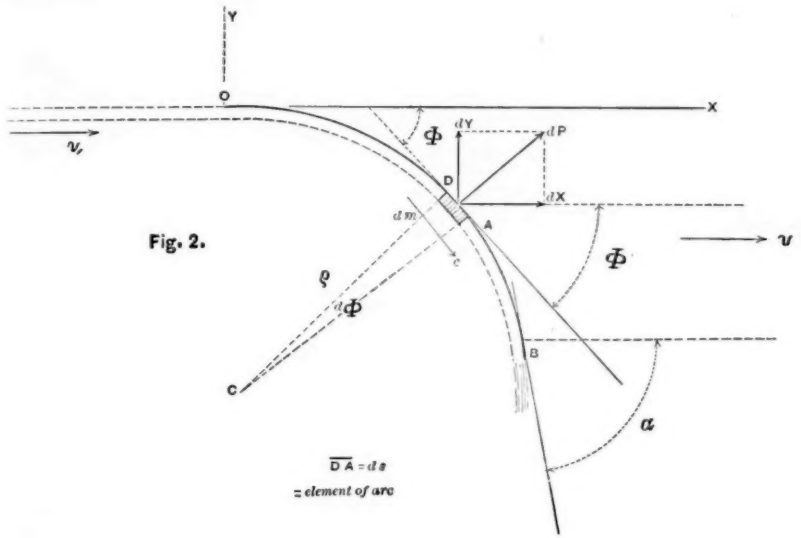


Fig. 2.

of the stream, $dm = \frac{F ds \gamma}{g}$, (where γ = weight of cubic unit of the liquid) presses normally with a force $dP = \frac{dmc^2}{\rho}$ against the vane, (c denoting the relative velocity $v_1 - v$ of the water) whose component in the direction of the vane's motion is

$$dX = dP \sin\Phi = \frac{dmc^2}{\rho}\sin\Phi = \frac{F\gamma c^2}{g}\,\frac{ds \sin\Phi}{\rho}.$$

But $ds = \rho d\Phi$ and substituting and making the summation for the whole arc of contact, we have the total impulse in the direction of the vane's motion, at the instant considered,

$$P = \int dX = \frac{F\gamma c^2}{g}\int_0^{\alpha} \sin\Phi d\Phi = \frac{F\gamma c^2}{g}[1 - \cos\alpha]$$

which, since $Fc = Q$ = quantity of water passing over the vane per second, may be written

$$P = \frac{Q\gamma}{g} c[1 - \cos\alpha]$$

(compare Coxe's Weisbach p. 1007). Since this result does not depend on the

length of curve, or its curvature, but only upon the relative velocity c, and the total angle of deviation a, we may reasonably conclude that the very short turn (Fig. 3) occasioned when the vane is straight, but c and a the same as before, produces a force $P=\frac{Q\gamma}{g}c[1-\cos a]$ nearly, and the work done per second

$$=\frac{Q\gamma}{g}c[1-\cos a]v.$$

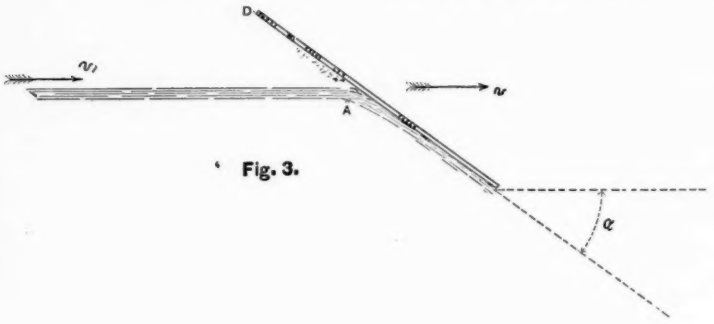


Fig. 3.

Some of the water, of course, takes the direction AD, being deviated an angle $(180°-a)$ from its original direction, and the nearer a is to 90° the more water follows AD. Weisbach considers this case on p. 1012 (Coxe's translation), whereas Rankine seems to neglect the circumstance altogether, except when $a=90°$, which, of course, gives the same P_x as if all the water had been deviated to one side only.

5. Supposing (Fig. 4) a curved vane to

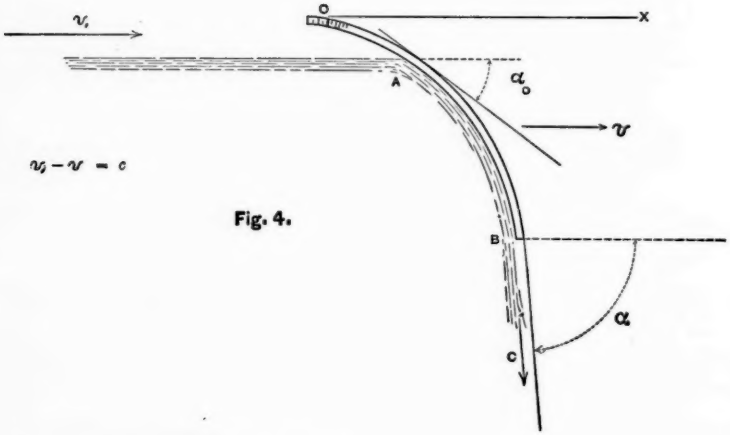


Fig. 4.

receive the water obliquely, instead of tangentially, other circumstances being the same as in Fig. 2, we have the impulse in the direction of X equal to the sum of two parts; that due to the sudden turn at A, $=\frac{Q\gamma}{g}c[1-\cos a_0]$; and that due to the presure of the elements along AB against that arc, which $=\frac{Q\gamma}{g}c\int_{a_0}^{a}\sin\Phi d\Phi=\frac{Q\gamma}{g}c[\cos a_0-\cos a]$

Whence the total X impulse is $P_x=\frac{Q\gamma}{g}c[1-\cos a]=$ same as if the water had impinged tangentially at O, (neglecting the alteration in the action

of what water takes the direction AO.)

By making $\alpha=180°$ and $v=\frac{v_1}{2}$ we cause the absolute velocity of the particles of water to be $=o$, on leaving the vane. That is, since, in that case, $c=v=\frac{v_1}{2}$, work done per second $=\frac{Q\gamma}{g}\frac{v_1}{2}[1-(-1)]\frac{v_1}{2}=\frac{Q\gamma}{g}\cdot\frac{v_1^2}{2}$ =total initial kinetic energy of the quantity passing over the *vane* per second, and not of that [Q_1] delivered per second from the stationary nozzle from which we may suppose the jet to be issuing. [Failure to recognize this distinction between Q and Q_1 makes Weisbach's work on p. 1010 (Coxe) incorrect. With his notation, if v is to vary, $Q=F(c-v)$ is also variable, and not constant, as he has treated it; hence the correct result in that problem is, Pv becomes a maximum for $v=\frac{c}{3}$, and not $v=\frac{c}{2}$. That Weisbach here incorrectly regards Q as the delivery from the nozzle, is shown in the example at the foot of the page referred to. This discussion Prof. Du Bois has reproduced without comment in the introduction to his translation of a portion of Weisbach's Vol. II. Similarly Prof. Trowbridge (p. 250 of the Eng. Mag. for March, '79) regards M as constant while u varies, whereas it is a function of u.

If a *series* of vanes is provided, connected with the same machine for doing work, and receiving the impulse of a single jet in turn, when the succession is once established it *is* true that the work done per second $=\frac{Q_1\gamma}{g}c[1-\cos\alpha]v$ and not $=\frac{Q\gamma}{g}c[1-\cos\alpha]v$; for the portion of the jet intercepted between two successive vanes is at liberty to finish its work on the forward vane, while additional work is being done on the hinder one; while the rate of work done on each vane is $=\frac{Q\gamma}{g}c[1-\cos\alpha]v$ so long as that vane receives any water].

6. In Figs. 2, 3, and 4, the direction of

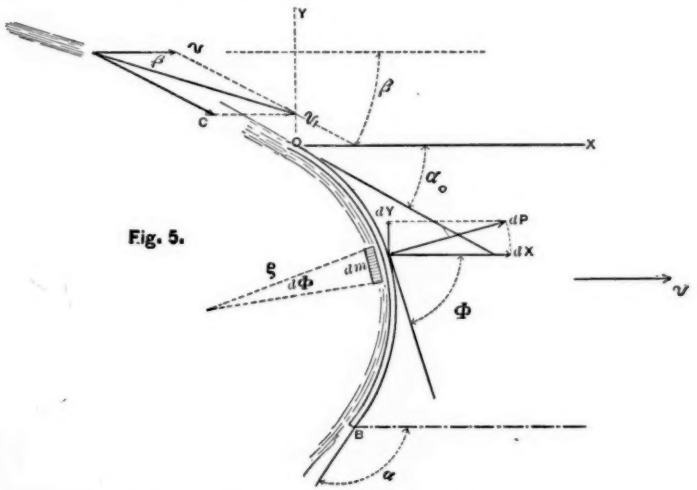


Fig. 5.

the jet has purposely been taken co-incident with that of the vane's motion, that the water may follow up the vane, as the motion proceeds. Let us now take the case of a jet coming *tangentially* into contact with a curved vane moving obliquely to the jet, (Fig. 5). v_1=absolute velocity of the water before contact with the vane; v=velocity of vane in a direction X, making an angle β with the absolute direction of the jet. We easily find $c=\sqrt{v_1^2+v^2-2v_1v\cos\beta}$, the relative veloc-

ity of the water, and a_0 $\left(\text{from } \sin a_0 = \frac{v_1 \sin \beta}{c}\right)$ the angle between c and X. As in connection with Fig. 2, so here we have by successive substitution,

$$P_x = \int_0^B dX = \int d\,P \sin \Phi =$$

$$\int \frac{dmc^2}{\rho} \sin \Phi = \frac{Q\gamma}{g} c \int_{a_0}^{a} \sin \Phi \, d\Phi$$

$$= \frac{Q\gamma}{g} c \,[\cos a_0 - \cos a]$$

=the force in the direction of the vane's motion, acting at the instant.

Here Q=Fc=volume of water passing a point on the vane per second (or Q= rate of passage over the vane) and its use arises incidentally, as a matter of mere algebraic convenience. As P_x is independent of the extent of arc, we may regard its value, found above, as still applicable to a sharp turn (Fig. 6), if $a - a_0$ is not large, *i. e.*, if we neglect the change in the action of the small amount of water taking the direction AO. Hence for Fig. 6 we have $P_x = \frac{Q\gamma}{g} c[\cos a_0 - \cos a_1]$.

The straight portion AD, of course exerts no pressure against the flat vane By uniting these two cases in the general case Fig. 7, P_x is the sum of the two parts $\frac{Q\gamma}{g} c\,[\cos a_0 - \cos a_1]$ due to the sud-

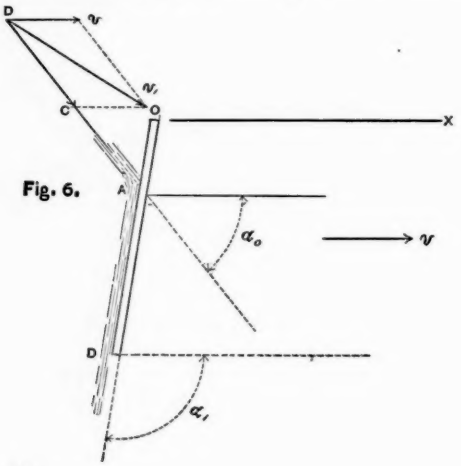


Fig. 6.

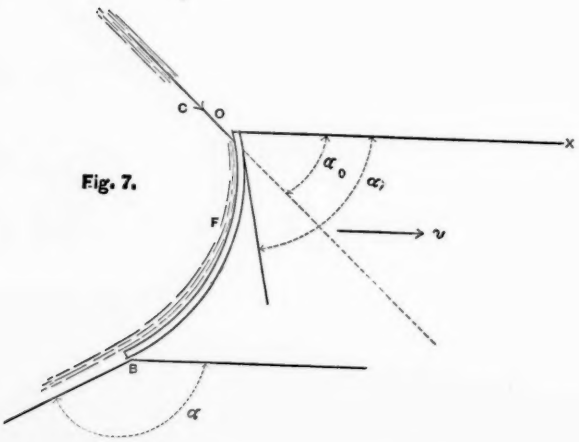


Fig. 7.

den turn, and $\frac{Q\gamma}{g} c\,[\cos a_1 - \cos a]$ due to the pressure of the water in contact with the arc OB; *i. e.*, as before, $P_x = \frac{Q\gamma}{g} c[\cos a_0 - \cos a]$ and the rate of work in $P_x v = \frac{Q\gamma}{g} c[\cos a_0 - \cos a]v$. That part of P_x due to the sudden turn might be called the effect of impulse, and the second portion the effect of reaction, following Rankine's idea; but the writer sees no ground whatever for distinguishing the nature of pressure on the arc above F (in Fig. 1, p. 249 of the March Eng. Mag. '79), where the relative deviation is gradual, from that below F where it is also gradual. The X components (see Fig. 5 of this article) of the normal pressures of elements of the stream above F, (Fig. 7) at any instant, are in the same direction as those of the elements below, while the Y components of both portions, though opposite in direction, are all nullified by the supports, which only allow a motion of the vane parallel to X.

7. Considering the vane in Fig. 7 as one of a series forming an "impact wheel," whose plane of revolution is perpendicular to the paper in that figure, we will then have, for reasons similar to those adduced in the last part of § 5, the work done per second

$$= \frac{Q_1\gamma}{g} c[\cos a_0 - \cos a]v,$$

where Q_1 = volume of water passing the nozzle or mouth piece of the jet, per second, care being taken to place them sufficiently near, that no water escape impact.

The expression last given is identical with that derived in another way (comparison of initial, and final, kinetic energies) by Weisbach, (Vol. II. § 231).

Enough has now been presented in reference to the action of water in a vane moving parallel to itself to show what is thought by the writer to be a clearer, and more logical and rigid method of analyzing the problem than any other he is acquainted with.

To show the application of the same analysis when the vane or channel rotates about an axis perpendicular to the plane of the water's motion, the particular case of an outward flow Fourneyron Turbine, working under certain conditions, will be considered; but as a necessary preliminary to its discussion, the following problem in mechanics needs investigation:

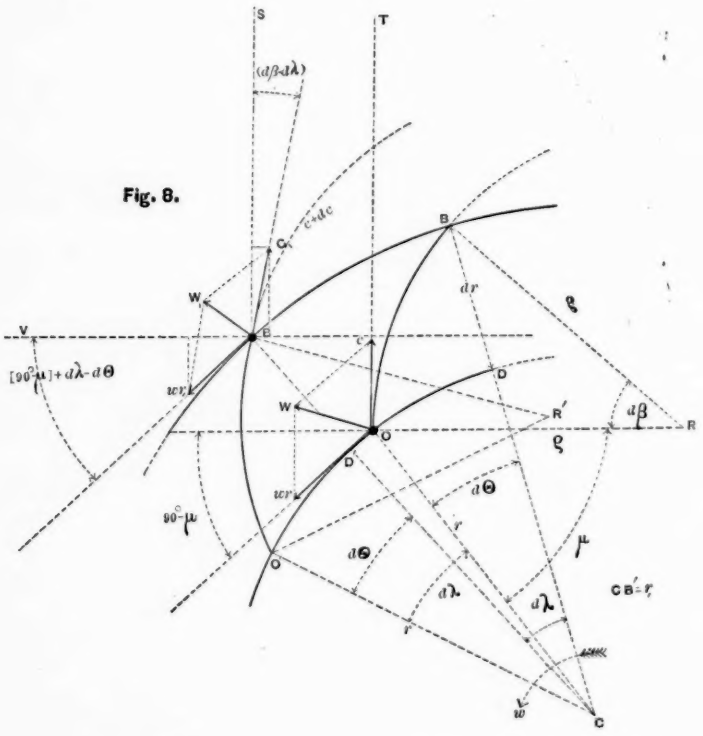
8. *Problem.*—Given a horizontal disk, revolving with a constant angular velocity, ω, about a vertical axis, and containing in a smooth curved channel, or groove, a particle whose mass is M, free to move without friction in the groove; required the normal pressure N, between M and the side of the groove, and also the law of variation of M's relative velocity, c, along the groove. [The last requirement is indeed solved by Weisbach (see pp. 610, 611, and 612, Coxe's translation of Vol. I.) by the employment of a fictitious centrifugal force; fictitious, because the particle in question is *not* compelled to follow the arc for whose radius and velocity that centrifugal force is computed. On p. 612, the (relative) energy stored is written $\frac{Mc_2^2}{2} - \frac{Mc_1^2}{2}$, whereas these two amounts of kinetic energy are those relative to *two different circumferences* of the top, so that their difference has no meaning, and cannot properly be said to be energy stored relatively to the top, since each circumference of the top has a different velocity. One of these faults counteracts the other, and thus a correct result is obtained].

As in a preceding paragraph, so here, we shall derive an expression for the rate of change (acceleration), consequent on supposing a slight motion of both disk and particle, of that component of the particle's absolute velocity which is in the direction of the normal (to the groove); and this acceleration (or retardation), multiplied by M, will give the normal pressure of the side of the groove against the particle, at that instant. While, to find the law of change of c, we need only write the rate of change in the tangential component (tangential to the groove) equal to zero, for no friction is considered; and from this last equation that law can be determined.

9. In Fig. 8, let C be the central axis of the disk, which is revolving with the uniform angular velocity ω, and OB an element of the arc of the groove or channel, whose radius of curvature is $= \rho$,

and whose extremities O and B, are radially distant, r and r_1, respectively, from C. Let μ= angle contained between the radii ρ and r. If, at the beginning of the instant dt (t being the independent variable), the particle is at O, having an absolute velocity w, the diagonal formed on c, its relative velocity along the groove, and ωr the velocity of rotation at that distance from the axis; then when dt has elapsed, the particle, being at B′, will have described the arc $OB = O'B' = cdt = \rho d\beta$, which subtends an angle $d\theta$ at the axis, the disk will have rotated through a small angle $d\lambda = \omega dt$, the particle is a distance dr further from the axis, and its velocity in the groove has increased to $c_1 = c + dc$, which combined with the velocity of rotation at that point, $\omega r_1 = \omega(r + dr)$ gives an absolute velocity w_1, differing in magnitude and direction from that w, at O. If, therefore, we divide the difference of the components of w_1 and w in

Fig. 8.



the direction OR (normal to the groove at O) by dt, we have the rate of change of absolute velocity in that direction, and multiplying this by M will give N the normal pressure which must exist between the particle and the side of the channel. Hence, draw B′V parallel to RO, and B′S perpendicular to it. The component of w_1 along B′V, *i. e.*, its projection upon it will be equal to the algebraic sum of the projections of ωr_1 and c_1 upon B′V; a corresponding statement can be made concerning w.

The following relations, evident from an inspection of Fig. 8, will be referred to in subsequent work, viz:

$$OB = cdt = \rho d\beta;\ \text{or,}\ \frac{d\beta}{dt} = \frac{c}{\rho} \quad . \quad . \quad . \quad . \quad (1)$$

$$rd\lambda = (\omega r)dt;\ \text{or,}\ \frac{d\lambda}{dt} = \omega \quad . \quad . \quad . \quad . \quad (2)$$

$cdt \sin \mu = dv$; or, $\frac{dr}{dt} = c \sin \mu$ . . . (3)

$rd\theta = cdt \cos. \mu$; or, $\frac{rd\theta}{dt} = c \cos \mu$ . . . (4)

Formulating the above reasoning we have

$$N = M \frac{1}{dt} \Big\{ \omega r \sin. \mu + c \times 0 - \Big(\omega (r+dr) \cos. [(90^\circ - \mu) + (d\lambda - d\theta)] - (c+dc) \sin. (d\beta - d\lambda) \Big) \Big\}$$

Putting for brevity's sake, $(d\lambda - d\theta) = d\gamma$ and $(d\beta - d\lambda) = d\delta$, and expanding, we have

$$N = \frac{M}{dt} \Big\{ \omega r [1 - \cos d\gamma] - \omega dr \sin. \mu \cos d\gamma + \omega r \cos. \mu \sin d\gamma + \omega dr \cos \mu \sin d\gamma + c \sin. d\delta + dc \sin d\delta \Big\}$$

Now reject all terms containing differential factors of the second order, among which is to be reckoned $(1 - \cos d\gamma)$ = vers. $\sin d\gamma$; and put $\cos d\gamma = 1$ and $\sin d\gamma = d\gamma$, etc. Whence, after restoring the values of $d\gamma$ and $d\delta$,

$$N = M \Big\{ \frac{cd\beta}{dt} - \frac{cd\lambda}{dt} - \omega \frac{dr}{dt} \sin \mu + \omega r \cos \mu \Big(\frac{d\lambda}{dt} - \frac{d\theta}{dt} \Big) \Big\}$$

Or, substituting from equations (1), (2), (3), and (4), after expanding, etc.,

$$N = M \Big\{ \frac{c^2}{\rho} + \omega^2 r \cos \mu - \omega c [1 + \sin^2 \mu + \cos^2 \mu] \Big\}$$

or, finally,

$$N = M \Big\{ \frac{c^2}{\rho} + \omega^2 r \cos \mu - 2\omega c \Big\} \quad \ldots\ldots (5)$$

as the value of the mutual normal pressure between the particle and the side of the channel. The reader will find it interesting to apply this formula to cases where N is known already from obvious considerations; *e. g.* when the particle has no motion relatively to the groove, and is prevented from increasing its distance from the axis by means of an obstacle at right angles to the radius vector, we have $c = 0$ $\mu = 0^\circ$ whence

$$N = \omega^2 M r,$$

the pressure due to centrifugal force as it should be. By placing the parenthesis, in the value of N, equal to zero, we have a condition to be satisfied at every point of a channel so formed that the particle shall describe a horizontal straight line in space, as if the disk were not there.

10. To find the law of variation of c, the relative velocity of the particle, it remains to find an expression for the rate of change in that component of the particle's absolute velocity which is parallel to the tangent OT, Fig. 8, and write it equal to zero, as there is no tangential force, the groove being considered perfectly smooth. As before, we project w_1 and w upon the direction OT (or B′S), and take the difference between the two projections. Hence the rate of tangential change of absolute velocity, putting $(d\beta - d\lambda) = d\delta$, and $(d\lambda - d\theta) = d\gamma$

$$= \frac{1}{dt} \Big\{ (c+dc) \cos d\delta - \omega (r+dr) \sin [(90^\circ - \mu) + d\gamma] - (c - \omega r \cos \mu) \Big\}$$

$$= \frac{1}{dt} \Big\{ -c(1 - \cos. d\delta) + dc \cos. d\delta + \omega r \cos \mu - \omega r \cos. \mu \cos. d\gamma - \omega r \sin. \mu \sin. d\gamma - \omega dr \cos. \mu \cos d\gamma - \omega dr \sin \mu \sin d\gamma \Big\}$$

Putting $(1 - \cos d\delta) = o$, $\cos. d\delta = 1$, $\cos. d\gamma = 1$, $\sin d\gamma = d\gamma$, and rejecting $\omega dr \sin. \mu d\gamma$; *i. e.*, neglecting all terms containing as factors differentials of the second order, we have, after slight reduction the form

$$\frac{1}{dt} \Big\{ dc - \omega r \sin. \mu d\gamma - \omega dr \cos \mu \Big\};$$

which becomes, after restoring the value of $d\delta$ and $d\gamma$,

$$= \Big\{ \frac{dc}{dt} - \omega \sin \mu \frac{rd\lambda}{dt} + \omega \sin \mu \frac{rd\theta}{dt} - \frac{\omega dr}{dt} \cos \mu \Big\}$$

Substituting from equations (2), (3), and (4) the last two terms disappear, and we have, imposing the condition (=zero)

$$\frac{dc}{dt} = \omega^2 r \sin \mu; \text{ or } \frac{cdc}{dt} = \omega^2 rc \sin. \mu;$$

or, finally, from equation (3),

$$cdc = \omega^2 r dr \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$\text{or } \int_{c_0}^{c} cdc = \omega^2 \int_{r_0}^{r} rdr;$$

i. e., $c^2 = \omega^2 r^2 - \omega^2 r_0^2 + c_0^2$ . . . . . (7.)

the same result as Weisbach states, on p. 612 (Coxe).

In (7.) c_0 denotes the known relative velocity of the particle and r_0 its known distance from the axis, at some previous instant, and we notice that c is *independent of the form of the path*, depending only on the distance r, from the axis, and constants.

(If a frictional resistance along the tangent, ΦN, were considered, we would obviously have

$$\frac{dc}{dt} = -\frac{\Phi N}{M} + \omega^2 r \sin\mu$$

11. To justify the application of equations (5), (6), and (7), to an outward-flow turbine wheel, we must have certain conditions realized, which are these: the wheel discharges into the air, the cross-section of the water in each of its channels diminishing from F_0 (at the inner circumference) as the relative velocity, c, grows larger, so that

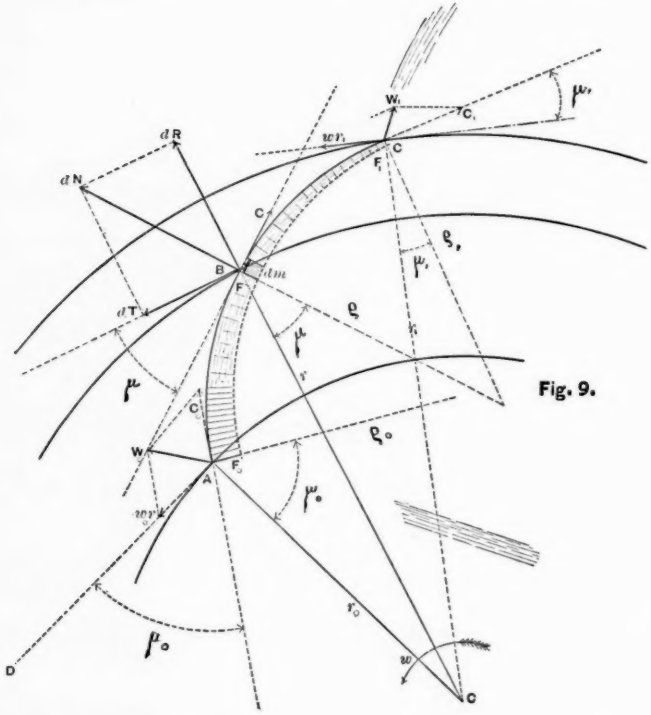


Fig. 9.

$Fc = F_0 c_0$. Also suppose the orifices of the guide channels to form a continuous series round the circumference of r_0, the inner radius of the wheel. The water is delivered from those latter stationary orifices with a known velocity w_0, upon the wheel, in a known direction (from each orifice) making the same angle with the radius at all points of the circumference of r_0. At the outset, at least, the initial relative velocity c_0, will be supposed tangential to the wheel-channel at the entrance. The wheel has a known, constant, angular velocity, ω.

Let AC, Fig. 9, be any curved float of such a wheel, revolving in a horizontal plane with an angular velocity ω, and B any point of the curved vane, or float. At any instant the whole length of the float is covered with water, whose cross-section and relative velocity at A are F_0 and c_0, the absolute velocity there being w_0, making such an angle with AD that

its component c_0 shall be tangent to the float at A. At any point, as B, the cross-section is F, and relative velocity c, according to the relations, $Fc=F_0c_0$, and that expressed by eq. (7.); *i. e.*, the channels of the wheel are not supposed to be filled with water, necessarily. At any instant each dm $(=\frac{F ds \gamma}{g}$, where ds denotes an element of the arc $AB=s$) is exerting normally against the float a pressure dN, which may be replaced by two components, one dR, radial to the wheel having no part in producing motion, and dT, perpendicular to the radius vector, r, of that point, which component alone is available for aiding rotation of the wheel, its moment about the axis being $=dTr$. Therefore if there are n floats in the wheel we have the total moment of rotation, at any instant,

$$M=n\int_A^C dTr \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

We have now only to make substitutions from preceding equations, so as finally to derive, if possible, M=function of Q, γ, v_0, v_1, r_0, r_1, μ_0, μ_1 and ω.

12. Knowing that $dT=dN\sin\mu$, and substituting the value of dN from eq. (5) remembering that the N and M of that equation are the dN and dm of our present problem, we have (8) transformed into

$$M=n\int_A^C dm\left\{\frac{c^2}{\rho}+\omega^2 r\cos\mu-2\omega c\right\}\sin\mu$$

As the further reduction is rather tedious, the successive steps will be simply indicated without rewriting the equation each time.

First, substitute

$$dm=\frac{F ds\gamma}{g}=\frac{F_0c_0\gamma ds}{gc}$$

and take the constant factor $\frac{F_0c_0\gamma}{g}$ outside of the integral sign.

Secondly, substitute

$$ds=\frac{dr}{\sin\mu}=\frac{cdc}{r\omega^2\sin\mu}$$

[from Fig. 8 and equation (6)].

Thirdly, substitute

$$\rho=\frac{ds}{d\beta}=\frac{dr}{\sin\mu\, d\beta}=\frac{cdc}{r\omega^2\sin\mu d\beta}$$

[from Fig. 8 and equation (6)].

Fourthly, from Fig. 8 we have, after inspection,

$$d\mu=d\lambda-d\beta;\ \therefore\ d\beta=d\lambda-d\mu$$

which is to be substituted.

Fifthly, (Fig. 8) $rd\lambda=\frac{dr}{\tan\mu}$ which substitute, remembering that $\tan\mu=\frac{\sin\mu}{\cos\mu}$, and we have

$$M=\frac{nF_0c_0}{\omega^2}\cdot\frac{\gamma}{g}\int_A^C\Big\{\omega^2 c\cos\mu dr$$

$$-\omega^2 cr\sin\mu d\mu+\omega^2 rdc\cos\mu-2\omega cdc\Big\};$$

that is,

$$M=\frac{nF_0c_0\gamma}{g}\cdot\frac{1}{\omega^2}\int_A^C\Big\{\omega^2 d(rc\cos\mu)-2\omega cdc\Big\}$$

or, since $nF_0c_0=Q=$ volume of water passing over the floats per second, which also $=Q_1$, passing through the guide channels per second, we have, after integrating $d(rc\cos\mu)$ between the limits $r_1c_1\cos\mu_1$ and $r_0c_0\cos\mu_0$, and cdc between c_1 and c_0,

$$M=\frac{Q\gamma}{g\omega}\Big\{c_1(\omega r_1)\cos\mu_1-c_0(\omega r_0)\cos\mu_0$$

$$-c_1^2+c_0^2\Big\}\ .\ .\ .\ (9)$$

a result independent of the shape of the float between A and C, depending only on the initial and final conditions at A and C respectively.

Consequently the work done per second is

$$\omega M=\frac{Q\gamma}{g}\Big\{c_1\omega r_1\cos\mu-c_0\omega r_0\cos\mu_0$$

$$-c_1^2+c_0^2\Big\}\ .\ .\ .\ .\ .\ .\ (10)$$

which may be easily shown to be identical with the result obtained by Weisbach's method of comparing the initial and final kinetic energies of Q_1, *i.e.*, work done on wheel per second = kinetic energy of water lost per second,

$$=\frac{Q\gamma}{g}\cdot\frac{w_0^2}{2}-\frac{Q\gamma}{g}\cdot\frac{w_1^2}{2},$$

for w_1 and w_0 are capable of expression in terms of c_1, ωr_1, μ_1, and c_0, ωr_0, μ_0, respectively.

13. If the initial absolute velocity v_0 were such in magnitude and direction that the initial relative velocity c_0 made an angle $\mu'>\mu_0$ with the wheel-tangent

AD Fig. 9, the force at A perpendicular to r_0, arising from the sudden turn, would be

$$P=\frac{Q\gamma}{g}c[\cos\mu_0-\cos\mu']$$

(just as in § 6, Fig. 7) and the work done by it per second

$$=P\omega r_0=\frac{Q\gamma}{g}[c_0\omega r_0\cos\mu_0-c_0\omega r_0\cos\mu']$$

and adding this quantity to that already obtained in equation (10) due to the gradual deviation, we have, for the case when the water arrives upon the wheel *non-tangentially*, work per second,

$$=\frac{Q\gamma}{g}[c_1\omega r_1\cos\mu_1-c_0\omega r_0\cos\mu'-c_1^2+c_0^2], \quad . \ . \ . \ . \quad (11)$$

the same as if the curve of the float had been so altered at A, as to make c_0 tangential. It certainly seems that some useful energy would be lost in eddying, etc., if the water arrived non-tangentially upon the wheel. As to practical experiments, which apparently have decided a greater effect to be produced when the water enters non-tangentially, it must be remembered that to realize in one of two experiments (with the same wheel and same form of floats) a tangential entrance, in the other a non-tangential, two different angular velocities are necessary; hence proper conditions for comparison do not exist. To the writer the following would seem a fair test: after one experiment has been made with non-tangential entrance, the wheel having a certain angular velocity ω, let another be made with precisely the same conditions, velocities, etc., except *that the inner curve of the float at A be so changed that a tangential entrance is realized.* A comparison of the rates of work in the two cases can then be made with some hope of deciding the question.

14. The horizontal water-wheel so far considered has been one working in the air, not under water, with its channels not necessarily filled, unless their form is such that the stream of water whose cross section is $F=\frac{F_0c_0}{c}$ happens to be of the same form as the channel (the channel must be no smaller, however). Sufficient has been done, however, in the treatment of this case, it is thought, to verify Weisbach's method of treating turbine wheels of the Fourneyron, Jonval, and Francis type, and, especially, to give a clear idea of the pressure exerted by the water at any point of the curved vane or channel against its surface, in the cases treated in this article.

THE DANGERS OF BAD PLUMBING.

By Mr. W. EASSIE, C. E.

From "The Builder."

DURING the Exhibition which was held in Leamington in 1877, I contributed some remarkable specimens of mal-construction in plumbing, and also some curious examples of leaden pipes into which holes had been gnawed by rats while seeking ingress to a house. I also showed several pieces of sheet lead which had been completely perforated by worms that had previously destroyed the unseasoned roof boarding underneath. In the present Exhibition I have laid upon a table some still more remarkable examples of defective and dangerous plumbing; and I may add that each specimen which I exhibit has been associated with death and disaster in some shape or other. In the few remarks which I will now proceed to make, I will endeavor to classify under the heads of Imperfect Jointing and Improper Treatment of Wastes, the sources of some of the evils complained of, so that each specimen may point its moral.

IMPERFECT JOINTING.

These faults will mostly be found in soil pipes. For instance, there is the slip joint, properly so called, in which one portion of the soil pipe has simply been dropped into another, without any filling up material or solder. A necessary result of this is, that the sewer gas escapes at all times into the house, when the soil pipe has to be erected in the interior of the house in the ordinary

wall chases. Even when the soil pipe had been led outside the house I have come across notable examples in which the sewer air has escaped from these open joints, and found an entrance into the house by way of the open windows. Cases of death due to this improper delivery of soil are very common indeed, and the victims are mostly servants who sleep in attics, the windows of which open above these pipes. Sometimes, even when the joints have been properly made with solder, but when the soil pipes inside the house have been insufficiently tacked to the wall or insufficiently supported, the weight of the soil pipe has sufficed, by dragging action, to open the joints, with the usual bad consequences. It is not an uncommon occurence to lay bare soil-pipe joints which have been made with putty, and tied over with canvas; or red lead joints, without the slightest attempt at soldering; and when these joints were dry an open annular seam has appeared, which has allowed an exit for the sewer air. Joints of this description are almost invariably found in the older class of houses, and I have exhibited, on several occasions, pieces of soil pipe, not more than 2 feet in length, upon which could be noticed each one of these samples of improper jointing. I need hardly say that faults of this kind are mainly attributable to the carelessness of the workman, who has been content with the worst of patching, instead of insisting upon an entire replacement of the worn-out pipe, as was his duty. I am only too well aware that very often the builder has orders from the owner to carry out the very cheapest repairs; but this ought not to be a valid excuse, because it is neither workmanlike nor business-like to treat so serious a matter as a soil pipe in this way, and he ought to know very well that a soil pipe cannot fulfill its duty properly unless it can sustain a column of water inside without trickling at the joints; and when the builder observes, upon taking down the casing, that a pipe has become eaten into holes by sewer air, or is abnormally thin, he should know that no amount of patching he can devise will remedy the defects, seen and unseen, in such a case.

The corrosion of soil pipes into holes is almost entirely due to the action of sewer gas, and will always be found present in some portion or other of an old soil pipe which has never been ventilated. Where disinfectants of certain kinds are freely used, the decay of the lead is greatly accelerated. When a soil pipe of this description is laid bare, the safest way is at once to remove it, and to replace it by a drawn lead soil pipe of proper thickness, duly ventilated by a continuation of the same diameter of pipe up to the roof, remote as possible from windows and chimneys.

There is another thing which a builder has a perfect right to refuse to do, and that is, to lead the soil from a water-closet into a rain-water pipe which descends inside the house, or has its extremity near any window. This is a very frequent cause of illness, even when such a rain-water pipe, made to do double duty, is led outside the house; as, for the most part, it will be found that the upper extremity delivers foul air perilously near the inmates. During the past year I have known cases of death traced to this very fault. The evil factor in such improper treatment is multiplied when the pipe has not been made of lead, but only of lengths of thin cast-iron down-pipe, which cannot properly be jointed or made air-tight. I say that no responsible builder should ever consent to the erection of such inadequate soil piping, or only upon the specification of an architect or engineer who dare risk it under certain conditions. Nor ought any one to make use of an iron soil pipe outside the house, unless it be thoroughly disconnected at the foot, and a current of fresh air thus continually passed through it.

IMPROPER DELIVERIES OF WASTES.

A very large percentage of the waste pipes of sinks are led direct into the drain, with only a bell trap inside the room, which is oftener than otherwise broken, or with its upper portion removed for the convenience of passing down, quicker than is needful, the pantry and other sink wastes. As a result of this, and especially in butler's rooms, where he perforce sleeps, in order to be close to the strong room, a regular highway for foul air is established into the rooms, bringing with it sicknesses of many kinds. It is the same

too often with housekeepers' rooms and servants' halls, in which sinks have been placed, and servants who are often obliged to pass the greater part of the day in such rooms suffer in consequence. The only remedy against this state of things is to cause the sink to deliver over the trapping water of an open gully outside the house, no matter what distance the pipe may have to go to reach the exterior of the building, and to provide, as well, a trap underneath the sink itself, in order to keep out the cold air, and the effluvium arising from the decomposing wastes in the gully. This latter is a point which is often overlooked.

The above state of things is sufficiently bad, especially in a large household, too profusely equipped with sinks in the basement; but it is, perhaps, nothing to be compared to the improper entries of housemaids' sinks into soil pipes or D-traps of closets. In nearly every instance when a foul smell is discernible upstairs, it will be found to arise from this improper connection between these wastes and the soil system. I am not now speaking of properly constructed housemaids' sinks, with ventilated traps underneath, which are purposely constructed for the removal of bed-chamber slops of all kinds, because these may be allowed in such cases to enter a properly ventilated soil pipe; but I refer rather to sinks merely intended to remove away the drips from hot and cold water taps, in which case the danger is greatly enhanced by the sinks being placed in passages close to bedrooms, and in proximity to the great air-shafts formed by the staircases. These kinds of sinks should invariably deliver in the open air, and may sometimes be conveniently and safely led to the upper head of a rain-water pipe.

Another disgraceful system which obtains in many houses, even of very modern construction, is the leading of the cistern waste or overflow into the trap of a closet. I have this year exhibited some startling examples of this dangerous practice, and I most earnestly call attention to the fact that drinking water is contaminated in this way to an extent which must be incredible to anyone who has not made the sanitary inspection of houses his special study. I have come to the conclusion that the wisest way to avoid the dangers consequent upon this improper treatment of a cistern waste is to treat the latter as an overflow, and point it through the wall in all cases where a standing waste cannot be led to deliver in the open air.

The few remarks which I have made upon the subject of the delivery of housemaids' sinks into the D-traps and P-traps of closets are equally applicable to the wastes and overflows of baths. An examination of my pilloried specimens will show that this practice is far too common. One can observe there the traps of closets, into one of which have been led the waste of a cistern supplying drinking and closet-flushing water, the waste of the housemaid's sink, and the waste and overflow of a bath. As may be observed there also, the wastes of baths, sinks, and cisterns have been taken into both cheeks of one D-trap. It is bad enough to place the bath in the same room as a closet, and I wonder how architects can persist in this evil association, but it is something horrible to think that the delivery of the bath waste is into the very foulest conduit. And yet this latter mistake is one very constantly practiced by plumbers who at least ought to know better, and who ought to feel themselves in a position to refuse to carry out such a practice, even if ordered to do so by a clerk of works. I have known instances in which death has entered a household by way of a bath pipe thus dangerously connected, the danger being enhanced by the frequent contiguity of bath rooms to bed rooms.

Nor can it be said that these errors of judgment, or worse, apply only to old houses, for I exhibit samples of closet traps, with bath, cistern and sink entries, which are palpably but lately from the plumber's hands. In the majority of cases the excuse cannot be urged that these mistakes have been perpetrated in order to save money or to scamp the workmanship, because many of these traps are really excellent specimens of skilled labor, and in some of them the wonder is how the painstaking workman could have brought his soldering iron into play at the wiped joints in so small a space. The faults are entirely, in such instances, due to total ignorance of sanitary principles, and to a slavish follow-

ing out of the traditions of the workshop.

When we come to the water closet itself, we are all bound to admit that there is a great deal still to be done in providing a faultless apparatus. Most horrible examples of death-dealing closets are to be found, especially in the area vaults of our best houses. I should, above all, like to see abolished the filthy D-trap, with its furrings of fœcal matter, the huge iron container, with its linings of ancient ordure, and the trap at the foot of the soil pipe, with its excremental cess pit. I would even like to see abolished all traps whatsoever to closets, and I am convinced that if plumbers will only follow the lead of our more advanced sanitarians in this respect, or at least more largely patronize the earthenware closets, that much solid good and absence from disease would accrue to the community. It is almost criminal for builders still to persist in the use of the pan closet, which, to my knowledge, was condemned by Mr. Chadwick nearly forty years ago, and how they can insist on fixing this dangerous contrivance without a ventilating pipe, is more than I can fairly understand. I will not believe for a moment that its use is continued in order to sell the D-trap with it, the making of which occupies the time of the apprentices, or to provide for a regularly recurring bill of repairs; but those who persist in its use lay themselves open to the charge that they are introduced for no other purpose. I think the sole reason for the patronage it obtains is to be found in ignorance, and a false estimate of its economy and cheapness of erection. And I am persuaded that if our builders would only take to heart the lessons taught by the inspection of the much better articles seen at the present day in sanitary exhibitions, they would refuse to have anything more to do with it.

There is another fault concomitant with the use of nearly all closets, and that is the leading of the waste of the tray or safe under the apparatus into the closet trap. It is almost invariably taken there in the commoner houses, and in a very large percentage also of the better class houses even yet, and one-half the smells which encounter one on entering into a closet room is due to this lamentable want of common sense and forethought in dealing with the closet essentials.

It is, perhaps, somewhat too much to expect that our tradesmen are all acquainted with the necessity for the disconnection of the house drains from the sewer by means of any of the numerous disconnection traps, constructed on various systems, now in the market. But until such a trap is provided between the house and the sewer, at some part of the house drain, the work has been only half done. Nor can there be obtained any absolute safeguard from sewer air or house-drain gas, or any thorough ventilation of the horizontal drain or vertical pipes, until some method of absolute disconnection be practised, and fresh air taken in at such a trap in order to be discharged at the ventilating pipes. No plumber, however perfect his work, can hope to witness really satisfactory results from his labor until this disconnection has been achieved.

In 1877 the German Railroad Union announced that it would award nine prizes of from $375 to $1,875, amounting in all to $7,500, for inventions of improvements made from 1872 to 1878 of the following three classes, viz., railroad construction, and apparatus used in construction, railroad equipment and its management, and railroad administration and statistics, or for important railroad publications. There were thirty-two competitors for prizes—three in the first, seventeen in the second, and twelve in the third group. In the first group a first prize, $1,875, was given for the Serres and Battig iron permanent way, and a third prize, $375, for a switch apparatus, invented by Blanel, of Breslau, which does not break the main track. In the second group a second prize of $750 for a railroad freight-car fastening, invented by Thomer & Köhazy, of Kaschau, and a third prize of $375 to Klose, a Swiss superintendent of motive power, for a speed recorder for locomotives. In the third group the only prize given was a third prize of $375 for a commentary on a criminal law of the empire which applies to railroad men.

THE TAY BRIDGE.

From "Engineering."*

THE court of inquiry appointed by the Board of Trade to examine into the causes of the failure of the large spans of the Tay Bridge commenced its sittings at Dundee on January 3d. On that day the members of the court, namely, Mr. Rothery, Wreck Commissioner, Colonel Yolland, and Mr. Barlow, the President of the Institution of Civil Engineers, first proceeded to examine the ruins of the bridge from the deck of a tug steamer, and then traversed the southern standing portion, after which they returned to Dundee, and took the evidence of a number of railway officials as to the occurrences on the night of the disaster. On Monday and Tuesday of the present week, the court again sat, receiving the evidence of eye-witnesses of the failure of the bridge, and that of the divers who have been employed to explore the bed of the river, and ascertain the present state of the fallen structure, and this portion of the inquiry having been completed, the court was on Tuesday adjourned *sine die*, it being as yet unsettled whether any further evidence shall be taken at Dundee or whether the subsequent meetings of the court shall be held in London. All that at present seems to be certain is that few if any further steps will be taken until some portion of the broken girders have been raised, or it has been determined that any attempt to raise parts of the structure in such a way as to throw a light on the mode of the failure is impracticable. Under these circumstances it is probable that there may be a considerable—although perhaps not unnecessary—delay before the inquiry is proceeded with, and this being so it appears to us desirable to comment upon some of the facts of the case as far as they are at present known, while there is yet time, by a careful examination of the débris, to strengthen or disprove the conclusions towards which they seem to clearly point.

And here we may remark that the examination of the local witnesses has added little to the information which was available almost immediately after the disaster, except that the statements of the divers of course afford particulars of the position of the first part of the train and of some portions of the fallen structure. The evidence of the eye-witnesses appears to prove pretty clearly that the train was proceeding steadily on its way up to the moment when the failure of the bridge occurred, and also that the several spans which gave way did not go all at once but successively; but beyond this it proves little or nothing. From an engineering point of view the most interesting evidence yet given before the court of inquiry is that of the divers taken during the sitting on Tuesday last. The explorations of the divers have not yet been sufficiently complete to enable a clear picture to be drawn of the present condition of the fallen structure, but as far as their statements go they appear to show pretty clearly that the overturned piers have been completely broken up, that the fallen girders are lying in a fairly continuous line from north to south on the eastern side of the piers—what was the east side being now the underside—and that the train when the bridge failed was partly on the fourth and partly on the fifth span from the southern end of the gap, its center being somewhat to the north of the fourth pier. The engine is stated to be lying some 50 feet or so from the fifth pier on the south side, while the tender, two third-class carriages and one first-class are lying between the girders following south from the engine. It will be remembered that thirteen spans have given way, and in the course of the inquiry these spans, with the piers which carried them, have always been numbered from the south side, and to prevent confusion it will be desirable to adhere to this notation. From the statements of the divers it appears that there is a gap in the top boom of the girders a short distance southeast of No. 4 pier, but the information concerning the nature of this gap is not at present at all clear. Altogether the evidence of the divers, although of much interest in many respects, is yet somewhat contradictory

* Of January 9th.

on certain points, and the present condition of the girders cannot yet be spoken of with certainty. As regards the condition of the remains of the piers, no evidence has as yet been laid before the court of inquiry, but we have ourselves carefully examined them, and we shall have something to say of them further on. Acting on a suggestion of the court, we may add, the railway company are, we understand, taking steps to have the remaining bases of the piers photographed, so that a permanent record of their condition may be obtained.

We have referred in the early part of this article to certain conclusions towards which the facts so far available appear to point, and before describing the present condition of the piers, and dealing with the lesson which this condition teaches, it is desirable, for reasons given below, that we should clear the ground by pointing out briefly certain facts bearing upon the theoretical stability of the structure.

In the course of our article on this subject last week we quoted from Mr. Edgar Gilkes' paper on the Tay Bridge, read before the Cleveland Institution of Engineers in 1876, some remarks to the effect that the wind pressure required to overturn the large spans of the structure would be not less than 96 lbs. per square foot, the exposed area of a large pier being taken at 800 square feet, and that of one span and of a train being also taken at 800 square feet each. In making this quotation, we pointed out that the train would have a considerably larger exposed area than assumed, while it was not safe to consider merely the surface exposed by the windward girder, but that some allowance should be made for the insufficiently shielded surface of that to leeward. We should not have again referred to this point pending the continuation of the official inquiry had it not been that very wild statements have appeared in several papers, some unduly depreciating, and others most unaccountably enhancing the probable stability of the Tay Bridge piers, and under these circumstances, and in view of the great interest which attaches to this question, it appears to us advisable to place plainly before our readers a few data which may not only enable an approximate estimate to be formed of the stability of the piers, but may also serve to indicate the relative importance of certain information which will, we trust, in due course be brought out during the official investigation.

From the figures given by us last week it will be seen that the cluster of iron columns forming the highest piers had, including the transverse bearers for the girders at the top, a height of about 82 feet from the top of the masonry, and the center of wind pressure upon it may be taken as 41 feet above that level. In the case of the girders the center of wind pressure would be about 95 feet, and in that of the train standing on the rails, about 93 feet above the masonry level. We may accept Mr. Gilkes' estimate of the surface exposed by the pier and the windward girder, while the exposed surface of the lee girder partially shielded as it would be by the windward girder and the train, may be fairly taken as half that of the windward girder, or say 400 square feet. The area exposed by a train of a length equal to one span (and the train which was on the bridge when it failed would be about this length) would be at least 1,600 square feet, and we may take it at that amount. Under these circumstances the overturning moment exerted by a wind pressure of 1 lb. per square foot would be:

$$800 \times 41 + 1200 \times 95 + 1600 \times 93$$
$$= 32{,}800 + 114{,}000 + 148{,}800 = 295{,}600$$

foot-pounds, or about 132 foot-tons; that is to say, it would be equal to a force of 132 tons acting at a leverage of 1 foot.

Let us next consider the provision made to resist this overturning force. We explained last week that the piers which failed consisted each of a group of six cast-iron columns, four of these being 15 inches, and the remaining two 18 inches in diameter, each of the columns (both 15 inches and 18 inches) being made, in the case of the higher columns, of seven lengths 10 feet 10 inches long united by flanges. In some of the piers a less number of lengths were used. The columns were filled with Portland cement concrete, and they were braced together by horizontal and diagonal bracing, the details of which we have still to learn. The 15 inch colums were placed in pairs 12 feet apart at the bottom and 10 feet at the top in the direction of the length of the bridge, while transversely they

were 9 feet 10 inches apart throughout. The 18-inch columns were placed singly, one on each side bearing near the point of the hexagonal pier of brick and masonry, their bases being 21 feet 10 inches apart from center to center transversely to the bridge and their tops 19 feet 10 inches, each column raking inwards 6 feet.

Now it is evident that there are three principal ways in which a pier constructed as we have described could fail under lateral pressure, and these are: (1) that it should turn over bodily on the base of one of the outer columns; (2) that the outer column on the lee side should yield by bending or crushing, thus enabling the pier to turn over on the bases of the adjoining pair of columns; and (3) that the bracing should fail, thus enabling the pier to turn on the bases of all the columns, the latter coming together like the leaves of a parallel ruler. These three modes of failure might of course be also partially combined, or the columns instead of giving way at their bases might fail at some point above that level. The amount of resistance to overturning in the manner first stated (presupposing that one of the outer columns was sufficiently strong to carry the load imposed upon it by that mode of failure, and that the bracing was sufficiently rigid to transmit the load to it) would be influenced by the manner in which the columns were fixed to the masonry of the pier, as unless that fixing could be relied upon the stability would depend solely upon the weight resting on the piers. Let us first estimate the stability under the latter circumstances. Taking the weight of the columns and bracing as 90 tons, that of a pair of girders at 190 tons, and that of the engine and such portion of the train as could be carried on the length of one span at 120 tons, we should have a gross load of 400 tons to be lifted before overturning could occur. This load would act at an arm equal to half the traverse base given by the outer columns, or $\frac{21 \text{ ft. } 10 \text{ in.}}{2}$ = 10 feet 11 inches, and it would thus have what we may call a moment of stability of $400 \times 10.92 = 4368$ foot-tons. The overturning moment due to a wind pressure of 1 lb. per square foot we have shown to be probably about 132 foot-tons, and the wind pressure, which would overturn the bridge under the conditions assumed, would thus be $\frac{4368}{132} = 33.09$—or say 33— pounds per square foot only. If the state of affairs we have just supposed existed, therefore, the overthrow of the bridge need occasion no surprise. If, on the other hand, the columns were well secured to the masonry, the resistance of the pier to overturning would be increased, for each ton of "hold" (as we may call it) of the windward column would increase the moment of stability by 21.84 foot-tons, and the hold of the other columns proportionately to the distances of their points of attachment from the base of the column on which overturning of the structure is assumed to occur. A contemporary of ours in some singular calculations published last week, has assumed that the three windward columns could exert a pull equal to 140 tons, but in making this statement it has apparently been forgotten that for this pull to be exerted it would be necessary for the fastenings of these columns to be such that they could directly lift some 2,500 cubic feet or so of brickwork and masonry—a matter for which, at any rate, there was no provision made in the present case. As to the manner in which the fastening down of the columns was really carried out we shall speak hereafter, for the present we shall merely consider the effect of such a moderate amount of holding power as could probably be obtained under the actual conditions.

Assuming then at each of the columns was so bolted down that it could not be lifted without carrying with it between 60 and 70 cubic feet, or, say, 5 tons of stonework, and still dealing with the assumption that it was possible for the whole pier to turn over on the base of the leeward column as a center, we have an addition to the righting moment above calculated of $5 \times 21.84 + 2 \times 5 \times 15.84 + 2 \times 5 \times 6 = 109.2 + 158.4 + 60 = 327.6$ foot-tons. Adding this to the 4368 foot-tons before obtained, we get a total of 4695.6 foot-tons, and dividing this by 132 as before, we get 35.6 lb. per square foot as the wind pressure which would under these conditions just balance the stability of the structure. We may here remark that although we have deemed it desirable to show what the

probable stability of the structure would be if the outer columns were of such strength and the bracing so rigid as to render the overturning of the whole structure on the base of one of these outer columns a possibility, yet we by no means admit that possibility in the present instance. In fact the calculations above given are useful chiefly as showing the amount of stability which with the weights assumed might be approached but never reached in such a structure as that with which we are now dealing. It is important to bear this fact in mind. Of course if the weights of a pier and its load were greater or less than we have assumed them to be, the maximum stability possible would be proportionately affected, and any correction due to this cause can be readily applied when the facts come out before the court of inquiry.

Next as to the second mode of failure above stated. In this case also the nature of the fixing of the columns to the masonry materially affects the question. If this fixing down be disregarded, and the stability of the piers be assumed to depend upon the insistent weight only, and if the metal of these outer columns be taken at $1\frac{1}{4}$ inches thick,* giving a sectional area of 66 sqare inches, then from the figures already given the compressive strain on the column will be $\frac{132}{66\times10.92}=0.183$ ton per square inch for each pound of wind pressure per square foot exerted on the structure. Thus a wind pressure of 30 lbs. per square foot would induce a compressive strain in the outer column to leeward of $5\frac{1}{2}$ tons per square inch, if it be assumed that the character of the bracing were such as to enable the whole work of maintaining the pier upright to be thrown on that column. If, on the other hand, this task be assumed to be distributed between the three lee columns, the strain would be (taking the sectional area of each 15-inch column at 54 square inches, and their distance from center of pier as 4.92 feet): $\frac{132}{66\times10.92+54\times2\times4.92}=0.105$ ton per square inch for each pound of wind pressure per square foot. With the compression distributed between the three leeward columns, however, the righting moment of the pier would, in consequence of the reduction in the effective transverse width of base, be much under that required to resist a wind pressure of 30 lbs. per square foot, and the maximum strain in the lee columns possible without any bolting down of the windward columns would therefore be, as we shall show directly, considerably less than the maximum which with sufficiently rigid bracing it would be possible to throw on the single outer column. Whether or not such long columns would resist the loads which might under the assumed conditions be imposed upon them would evidently depend entirely upon the manner in which their several component lengths were fitted together and upon the efficiency of the bracing to resist lateral bending, both points upon which evidence has yet to be forthcoming. We may remark, however, that the assumption that it would be possible for the compressive strains per square inch on the lee side columns to be equally distributed is an extremely favorable one, and one scarcely likely to be realized in practice.

If the fastening down of the columns to the masonry be in the first place assumed to be of no value, then it is evident that the maximum compressive strain which could be thrown upon the lee columns would be equal to the whole weight of the pier and its insistant load, or 400 tons, as we have taken it. Distributed between the three lee columns this would give a strain on the sectional areas above given of $\frac{400}{66+54+54}=2.3$ tons per square inch, or of $\frac{400}{66}=6$ tons per square inch on the outer column, if it be assumed to be possible for that column to carry the whole load. If, on the other hand, the fastening of the columns to the masonry of the pier be taken into account the compressions on the lee columns will be in no way affected until the maximum possible loads without fastenings have been reached, but beyond this point the compressive loads on the lee columns will equal these maximum loads, just stated, plus the tensile

* This appears to be the average thickness of all the columns, although there is some slight variation in the dimensions of the remains of those which we have measured.

strains on the windward columns. It will thus be seen that the fastening down of the columns to the masonry in no way relieves the compressive strain on the lee columns as a whole, although it facilitates the distribution of the strain between them, and of course augments the resistance of the pier to overturning. We have already shown that assuming the piers to have failed in the manner first stated and the columns not to be bolted down, the overturning moment required would be about 4368 foot-tons (this being the moment given by a wind pressure of a little over 33 lbs. per square foot); and to further explain the point with which we are now dealing, it will perhaps be worth while to calculate to what the extent the stability would be modified if the columns are bolted down and the compressive strain on the lee side be assumed to be equally distributed over the three columns, instead of being borne by the outer one only. In the case we are now considering, the windward and leeward groups of columns may be regarded as forming the booms of a vertical girder, and the horizontal distance between the centers of gravity of the sectional areas of these booms will, in the case of the Tay Bridge piers, be almost exactly 14.4 feet. For reasons which we shall explain hereafter, it would probably be scarcely fair to assume that the tensile strain, which each windward column could be expected to stand without disturbing the stonework, would exceed 5 tons, and taking it at that amount we have $5\times3\times14.4=216$ foot-tons as the moment of stability due to the bolting down of the windward columns in the case we are now considering. In this case also the superincumbent weight of 400 tons will act at an arm of $\frac{14.4}{2}=7.2$ feet, and the moment of stability given by it will thus amount to $400+7.2=2880$ foot-tons. Adding to this the 216 foot-tons above obtained we get a total of 3096 foot-tons, which divided by 132 foot-tons (the overturning moment due to a wind pressure of 1 lb. per square foot) gives $\frac{3096}{132}=23\frac{1}{2}$ lbs. per square foot only as the wind pressure which would balance the stability of the pier under the conditions assumed. In this case the load on the group of three leeward columns would equal the load on the pier, plus the tensional strain on the windward columns, or $400+15=415$ tons, and as the combined sectional area of the three columns is 174 square inches the compression would be $\frac{415}{174}=2.39$ tons per square inch. It will be seen from the figures just given how greatly the stability of the structure is impaired, if it be considered that the conditions were such as to cause the three leeward columns to share the compressive strain due to the action of the wind equally between them, instead of the outer column alone taking the major share of the work.

We now come to the third mode in which the pier might have given way, namely, by a failure of the bracing between the columns, and although it would be idle to attempt, in the absence of trustworthy information as to the details of this bracing, to form a quantitative estimate of the strength of this part of the structure, yet it is advisable to say a few words as to the light thrown upon this point by the calculations we have already given. If we assume that the destruction of the bridge was caused by a failure of the piers—and with the evidence now available it is difficult to arrive at any other conclusion—it must then be conceded that these piers would fail at their weakest part, and as we have shown that the piers could probably be overturned as a whole under the most favorable conditions by a wind pressure of about 35½ lbs. per square foot, it follows that if the capsizing of the structure took place owing to the failure of the bracing, it took place under the influence of a wind pressure less than this. How much less, it is of course impossible to say in the absence of precise particulars of the bracing and of the mode of erection. To the information which these particulars will afford we look forward with great interest—an interest which will be shared by a large number of our readers—for, as will be seen from the notes which we give below, the remains of the fallen piers afford strong reasons for supposing that it was through a failure of the bracing that the overturning of the piers occurred. We have now arrived at the point at which it is

desirable to give an account, as far as we can, of the remains of the broken structure.

From the evidence given before the court of inquiry on Monday last by Mr. Roberts, the locomotive superintendent at Dundee—who, it will be remembered, explored the northern portion of the bridge on the night of the accident—it appears that the end of the northern portion of the structure now standing remains in practically the same condition it was immediately after the failure of the large spans occurred. Let us describe what that condition is, dealing first with the aspect of the structure from above on the north side. Standing at the southern end of the northern portion of the bridge, and looking down, the columns of the terminal pier are seen to be all standing, with the tie-rods all right except on the southern face, where they are adrift, owing to the lugs of the columns on that face being mostly broken off. None of the tie-rods are broken, but only the cast iron crosses and the lugs. There seems to have been absolutely no connection between the portion of the bridge which has been carried away and the standing portion except the rails and the gas pipe handrail. The 9-inch by 3-inch flooring planks butted at the edge of the crossbeam at this point.

The ends of the girders of the large span lay on a kind of shelf on the ends of the shore span girders, and apparently without any bolting. The girders of the large span seem to have slipped off sideways at this point, and when the inner edge of the eastern girder reached the edge, the piece of the shelf broke downwards, but not off, showing apparently that the girder had a large horizontal component in the direction of its motion, and that its motion sideways was probably rapid. The western girder, on the other hand, seems to have struck at the point marked B on the sketch, and to have dropped down, clearing away in its fall a light crossbeam between B and C, which light crossbeam is now lying immediately underneath at the base of the pier. The end of the girder in falling broke away the tie-rod fastenings, crosses and lugs, as has been already mentioned. The guard rails at the north end project about 9 feet beyond the standing portion of the structure, and the projecting portions are considerably curved towards the east. The other rails are carried away from a point a short distance within the end of the standing portion of the bridge. We shall have more to say about this northern end of the bridge hereafter when speaking of the bracing.

In the case of the end of the portion of the bridge left standing on the southern side of the river, the guard rails are seen, on looking up, to be bent over obliquely to the east. The two ordinary rails each project nearly straight for about 3 feet, but the piece on the western side carries fishplates, and these are bent to the eastward nearly to the same rake as the guard rails. The top shelf pieces are not damaged apparently, but the light cross-beam in front is lying below as in the case of the pier at the northern side.

An examination of the wreck at the bridge at this point indicates strongly the probable order of the steps in the failure of the structure. The now standing pier columns at the south end of the gap are but little injured. Remembering that the six columns form a hexagon, with the north and south sides longer than the others, and that the adjacent columns are braced together with horizontal bars and diagonals, and that there are also cross sets of bars, making altogether eight planes of bracing, we may, by noting which of the parts of the bracing have given way in the various standing columns, see clearly how the bridge has failed. In the south end standing pier each column consists of six lengths. The face lying east and west on the north side of the pier—that is facing the gap—shows the three upper pairs of diagonals adrift, and the first and second double horizontal ties also detached, all of these by the fracture of the cast-iron snugs. The fourth diagonal from top east corner is also detached, as are also all the horizontal round diagonal ties; the cast-iron corner brackets, to which these latter have been fastened, have in almost every case been pulled away, breaking their flanges. The rest of this pier structure is apparently uninjured. This is the last standing pier over which the train passed.

Returning now to the standing pier at

the north end of the gap, we find a much greater damage, the effect of the straining, and a fairly clear proof that the diagonal bracing had given way, at all events partially, some time before the last wrench occurred which brought down the bridge. In our description the sloping diagonals will be denoted as ties or struts, according as they would be in tension or in compression when the top of the structure was moved to the east, that is, as the bridge fell. The diagonals were, of course, valueless as struts, and the name is only here given to them to facilitate the explanation of affairs. Looking north at the south face of this pier, which has five tiers of columns, we see that all the bracing and the horizontal bars are away on this face, except the lowest tier of horizontal bars. There are four of the strut diagonals hanging, the tension ones and their cast-iron snugs are all away.

On the north face all the struts are intact, and also all the horizontal compression bars; but all except the lowest one of the tension diagonals are detached by fracture of the cast-iron snugs to which their lower ends were attached. The horizontal bars, and some of the diagonals in the south face, have been carried away by falling débris. Still, at the same pier, on the south-east face, the top tier has both diagonals, those of the next two tiers are hanging, the next compression bar and both diagonals are gone, and the lowest tie is hanging, so that only one of the tension diagonals is here. The north-west, and south-west, and north-east faces have all their diagonals and bars intact, except the second tie from the top on the north-east face. The diagonals are of flat iron single, $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch, with cottered fishplates on their lower ends, and attached to the cast-iron columns close to the flanges by one $1\frac{1}{8}$ inch bolt in a hole $1\frac{3}{8}$ inch in diameter. If the bolts had fitted the holes, then any slackness of these ties would have been seen as bending of the struts, but they may have been slack, or not all tight, and nothing would be shown wrong. The horizontal double bars are of pairs of channel irons $6\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{2}$ inch, placed back to back $2\frac{1}{2}$ inches apart. There are also horizontal round bars placed diagonally between the four 15 inch columns; the cast-iron attachment of these seems to have been an afterthought, it is at least not a very well planned attachment.

The evidence of the working of the columns is abundant on this pier. The east column is cracked from north round by east to west by north, and the bolts of broken part on north-east column, at base are broken from north by west to east. The south bolt of this flange has shorn across at the joint of the flanges at the base. The north-west column is broken from west round by north to east. These breaks are all at the lower flange. The west by south bolt here has broken by tension at $\frac{1}{2}$ inch from top of column flange, the bolt is $1\frac{1}{4}$ inch, and there are, as we shall explain hereafter, eight of these bolts in each flange. The west point column has not cracked at the joint, but the two stones to which the base is bolted have been moving, and the cake of cement about 1 inch thick is broken, showing the lower end of bolt holes through the cast-iron bases and continued through the two top courses of coping stone—the only bolts in the stone foundation. The south-west column is intact, except where the snugs for diagonals are broken off. The south column is broken across at the bottom from north-east, round by east to west, and the whole column has shifted $\frac{3}{8}$ inch towards the east. The second tier of columns has at the top a provision for some other kind of fastening. On each column the snug for the braces is continued down as a rib about 3 feet, and there are eight additional holes in it, but it seems none of these have been used.

Looking up now at the top of these columns, we observe that the three on the east have practically no connection with the three on the west, and even each of the sets of three is not at the top concentrated to one position. The caps are of riveted structure in the form of a capital A laid on its flat on the three columns; the bar of the A projects a little over, and forms the shelf for the girder end. As there is a distance of about 5 feet transversely between the centers of the tops of the columns, a slight inclination of this cap will permit the sloping outer column to move out to be vertical. It is said to be 1 foot

inclined now, but taking the height at only 60 feet, a rise of but one-tenth of an inch is all the sloping column requires in moving the vertical position, and as the other columns would be going down hill at the same time that the sloping column was rising, there would be only the stiffness of the columns to prevent lateral displacement, and gravity would be neutral.

From the appearance of the wreck one can certainly gather no confidence in the combined action of the diagonal ties. They may have gone, first that one which happened to be tightest, and the others to follow. The bridge has been expected to practically sit still by gravity, but the diagonal ties seem to us to have been very poor assistance to stability in this case, and an inspection of the pieces leaves the impression that when the train came on the high girders many of the ties may have been already detached, and perhaps some of the columns cracked at No. 5 pier, where the girders were not connected, and where the swaying of the girders by the wind would be greatest. The condition of this pier, and likewise of No. 9, where the girders were also not attached, we shall describe further on.

We now come to the condition of the piers which carried the fallen spans, and in describing these we shall commence from the south side, and give the piers the numbers by which, as we have already mentioned, they have hitherto been indicated in the evidence given before the court of inquiry, the pier at the northern end of the most southerly fallen span being called the first pier and so on. It will be remembered that these piers are of brickwork up to about high water level, but that above this is a stone capping of four courses of masonry of the aggregate thickness of about 5 feet. This being premised we will describe the present condition of the piers in regular order.

On pier No. 1 two lengths of the columns are standing with their tie-rods and foundation plates, the columns being almost intact. In the case of the eastern and south-eastern columns, the tops and a few inches of the columns themselves are broken off. On the north and the south faces all the tie diagonals are detached, the east column is broken at foot on south-west face, one tie diagonal stands, all the other diagonals there are detached. On the other three faces, those towards the north, all the diagonals are intact, except one tie. And here we may explain that each column springs from a foundation plate bolted to the masonry, and to which the column is itself bolted by eight bolts, these bolts being, for the 15 inch columns, $1\frac{1}{8}$ inch in diameter. In the case of the 18 inch outer columns the foundation plates are 4 feet square, while for the 15 inch columns they are 3 feet 10 inches in diameter, by $1\frac{3}{4}$ inch thick. Each foundation plate carries a socket or base about $22\frac{1}{2}$ inches high, the socket being stiffened by eight radial ribs. Four of the radial ribs first mentioned are bossed, to allow of the passage through them of the $1\frac{3}{4}$ inch bolts securing the foundation plates to the masonry, while in the case of two others, provision is made for the attachment of the bracing. The columns average, as we have already stated, $1\frac{1}{4}$ inch in thickness, and their flanges are of about the same thickness, those of the 15 inch columns being 23 inches, and those of the 18 inch columns 27 inches in diameter. The lengths of the columns have also male and female ends. With these preliminary remarks we may now continue our notes on the state of the remains of the fallen piers.

On pier No. 2 the six foundation plates are all right with some portions of the columns on the eastern side, but all above is gone. Portions of three of the columns are lying on the pier.

On pier No. 3 the foundation plates are in place, and one length of column stands, but the tops of these portions of the columns are gone. The stone work is all good.

On pier No. 4 the foundation plates are also all right with portions of the six columns attached, and hanging over on the *west* side. This would appear to indicate that this pier failed at some height above the masonry, the lower lengths of the columns being pushed over in the opposite direction to that in which the chief mass fell.

In the case of the piers so far mentioned, no stonework is out of place, but at about one-fourth of the adjacent span south of the fifth pier the engine is lying, and on this pier, No. 5, the stone-

work has been displaced. It will be remembered that the thirteen spans which fell, consisted of three continuous groups, the most southerly group consisting of five spans, and the two more northerly groups of four spans each. The junctions of the groups thus occurred on piers No. 5 and No. 9, and it is perhaps not without significance that in the case of these two piers the stonework is exceptionally injured.

Mounting on the masonry it is seen that all the first tier of columns is lying inclined, the stone at the west corner being lifted and still attached to the column base, but the column itself being broken off. Only the two stones at the west corner are displaced here, the others not being disturbed, and the foundation plates being fast to the stones.

On pier No. 6 the foundation plates are all good, but the columns have broken through the flanges or bolts. It may be remarked here that the cement concrete with which the columns were filled appears to be as hard as stone. We mention this because reports to the contrary have been circulated.

On pier No. 7 the foundation plates are all good, but some of the columns have broken off through the flange. Five columns are lying about the pier. In the case of pier No. 8, the stonework is all sound, and the foundation plates are intact. The first tier of columns are hanging about the pier.

On pier No. 9 the stonework has gone in the same manner as on No. 5, but worse. That is, the angle stones on the western side have lifted from their beds, but they are still on the pier. The stonework on the southern side of the pier is also shaken, the brickwork, however, being intact. The columns have in this case evidently lifted the stones. The first length of the western and south-west columns are lying canted over with their bases and two upper courses (the third and fourth) of stones attached, the stones lying on edge and showing the bottom of the third course. The dowel bolts tying the upper courses of stone together do not come through. In the case of the south-west column, the fourth course stone and a half of the third course is split through a dowel bolt hole, showing the thickened lower end of the bolt about 1½ inch short of being through the third course of stone. This case seems to fairly represent the fastenings of the stones throughout, the dowel bolts only passing through the two upper courses, and there being no connection—beyond that given by the cement—between these upper courses and the first and second courses below them. It is this mode of fixing which has led us to place such a low limit in our calculations on the amount of tensile strain which the windward columns might be expected to withstand. The bolts by which the foundation plates are secured—and which are not the dowel bolts—appear to enter the top course of stones only; but on this point we cannot speak positively. The bolts by which the foundation plates are fixed, however, have in no case failed, all the bases on all the piers, so far as they can be seen, appearing to be firmly attached to the top course stone. In the few cases where the foundation plates are absent the stones have gone with them.

On pier No. 10 the stonework is very little disturbed. At the western corner there are cracks, but they do not extend through the stonework. The bases of the columns are here all intact, and on every one of them is a piece of the flange of the corresponding column, all these fragments being portions of the western side of the flanges. Some of the fragments include two bolt holes, and are broken through the next two bolt holes, while others similarly broken include one bolt hole only. On the base of the south-west column stands a portion of the neck of the column about 3 inches high on the western and 9 inches on the eastern side. The lower connections between the bases of the columns are here also intact, except that one pair of tie-rods on the eastern side have been bent by the columns falling on them. Three lengths of columns lie on this pier overturned towards the eastern side.

In the case of pier No. 11, the stonework has suffered considerable injury, and the remains of the columns are lying about unevenly with ends of the tie-rods attached. Towards the northern side of the pier all the stonework is intact, and three foundation plates remain fixed in position. The other foundation plates have been carried

away with the stones to which they were fixed.

Lastly, on No. 12 pier the west corner or cut-water stone of the upper course—a stone about 4 feet square—is gone, and the stone below it, which measures about 6 feet by 6 feet 6 inches, is broken through the bolt holes. The bolts have gone through the two top courses only. With the exception of the foundation plate at the western corner, which has gone with its stone, the bases of the columns are all in position. There are four lengths of columns lying on this pier, and judging from their position, the canting over of the structure has first been towards the east, but in falling it has got set back towards the west. The column at the north-east corner has got canted round about 90°, and it is now standing nearly upright, but resting only on three bent tie-rods. It is somewhat dangerous moving about it. From what we have stated it will be seen that altogether the piers at the northern end of the fallen length of the bridge are in a worse condition than those towards the southern end.

We have now laid before our readers the facts connected with the failure of the Tay Bridge as far as they are at present known to us; and in bringing this somewhat lengthy article to a conclusion, we have but few remarks to add. It would be hazardous at this early state of the inquiry to urge strongly any view as to the precise manner in which the breakdown of the structure occurred; but the facts so far ascertained certainly point prominently to certain conclusions which we have indicated generally in the course of the foregoing article. On the question as to the amount of stability which the structure actually possessed, we have no desire to enlarge further on the present occasion; but the calculations we have given, together with the facts we have collated, certainly show that there is every reason to believe that it was vastly below the amount usually considered to be necessary for such works, both in this country and abroad. This, however, is a point to which the attention of the court of inquiry is certain to be prominently directed, and in taking leave of the subject for the present, we can only express a hope that the inquiry may be so conducted as to thoroughly sift all doubtful features in the design of the bridge, and to do away with the chance of any similar failure occuring in this country.

ON THE SHAPE AND SIZE OF THE EARTH.*

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III.—The Earth as an Ellipsoid.

Just as the sphere is a particular case of the spheroid of revolution, so the spheroid is a particular case of the ellipsoid. The sphere is determined by one dimension, its radius; the spheroid by two, its polar and equatorial diameters; while in the ellipsoid there are three unequal principal axes at right angles to each other which establish its form and size. Like the spheroid the ellipsoid has all its meridian sections ellipses, but the equator instead of being a circle is an ellipse of slight eccentricity and its two axes, together with the polar axis of rotation, constitute the three principal diameters. Let a_1 and a_2 denote the greatest and the least semi-diameters of the equator of the ellipsoid and b the semi-polar diameter. The ellipticity of the greatest meridian ellipse is then

$$f_1 = \frac{a_1 - b}{a_1}$$

and that of the least is

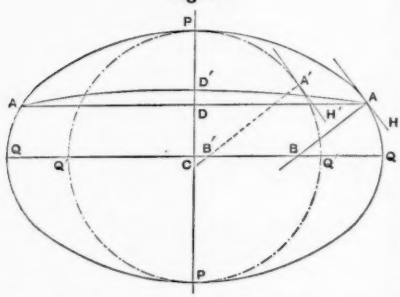
$$f_2 = \frac{a_2 - b}{a_2}$$

while the ellipticities of all the other meridian ellipses have values intermediate between f_1 and f_2. For the equator the ellipticity is $\frac{a_1 - a_2}{a_1}$. When the values of a_1, a_2, and b are known, the dimensions and proportions of the meridian ellipses and of all other sections of the ellipsoid can be easily found. In such a figure,

* Three lectures originally prepared for the Civil Engineering Students of Lehigh University, as introductory to a course in Geodesy.

however, the curves of latitude, with the exception of the equator, are not plane curves, and hence cannot be called parallels; this results from the definition of latitude and may be seen from the following diagram. PP is the polar axis, PQPQ the greatest meridian section of the ellipsoid, and A a place of observation upon it, whose horizon is AH and latitude ABQ, AB being the direction of the plumb line at A, which of course is perpendicular to the tangent horizon line AH. Let now the least meridian ellipse, projected in the line PP, be conceived to revolve around PP until it coincides with the plane PQPQ and becomes seen as PQ′PQ′. To find upon it a point A′ that shall have the same latitude as A, it is only necessary to draw a tangent A′H′ parallel to AH touching the ellipse at A′, then A′B′ perpendicular to A′H′ makes

Fig. 8.



the same angle with the plane of the equator QQ as does AB. If the least meridian section be now revolved back to its true position A′ becomes projected at D′. We thus see that while a section through A′parallel to the equator is an ellipse ADA, the curve joining the points having the same latitude as A is not a plane curve but a tortuous line AD′A.

The process for determining from meridian arcs an ellipsoid to represent the figure of the earth does not differ in its fundamental idea from that explained in the last lecture for the spheroid. The normal to the ellipsoid at any point will usually differ slightly from the actual vertical as indicated by the plumb line, and these deviations are taken as the residual errors to be equalized by the method of least squares. An expression for the difference of these deviations at two stations on the same meridian arc is first deduced in terms of four unknown qualities, three being the semi-axes a_1, a_2 and b, or suitable functions of them, and the fourth the longitude of the greatest meridian ellipse referred to a standard meridian such as that of Greenwich; and in terms of four known quantities, the observed linear distance between the two stations, their latitude and the longitude of the arc itself. Selecting now one station in each meridian arc as a point of reference, we write for that arc as many equations as there are latitude stations, inserting the numerical values of the observed quantities. These equations will contain four more unknown letters than there are meridian arcs, and from them by the method of least squares as many normal equations are to be deduced as there are unknown quantities, and the solution of these will furnish the most probable values of the semi-axes a_1, a_2 and b with the longitude of the extremity of a_1, and also the probable plumb-line deviations at the standard reference stations. The process is long and tedious, but it is easy to arrange a system and schedule, so that, starting with the data, computers may execute most of the labor, who have no idea at all of the whys and wherefores involved.

The first deduction of an ellipsoid to represent the figure of the earth was made in Russia, by Schubert, about the year 1859. His data consisted of eight meridian arcs, the Russian, English, Prussian, French, Pennsylvanian, Indian, Peruvian and South African, embracing in total an amplitude of about 72°. These were combined in a manner different and less satisfactory than that above described, the results, according to Listing, being,

$a_1 =$ 6 378 556 meters.
$a_2 =$ 6 377 837 "
$b =$ 6 356 719 "
$q_1 =$ 10 002 263 " $f_1 = \frac{1}{292.1}$
$q_2 =$ 10 001 707 " $f_2 = \frac{1}{302.0}$
$Q =$ 10 018 849 " $F = \frac{1}{8881}$

Long. of $q_1 = 40°\ 37'$ E. of Greenwich.

Here q_1 and q_2 are the quadrants of the greatest and least meridian ellipses, Q the quadrant of the equator, and f_1,

f_2 and F the corresponding ellipticities; a_1 and a_2 are the equatorial semi-axes and b the polar semi-axis. By referring to a map of the earth you will see that the maximum meridian ellipse passes through Russia and Arabia in the eastern continent and through Alaska and the Sandwich Islands in the western, while the minimum ellipse cuts Japan, Australia, Greenland and South America.

It is, however, Clarke, of the British Ordnance Survey, to whom we owe almost all our knowledge of the dimensions of the earth as an ellipsoid. His first investigation was made in 1860 and embraced the data from the Russian, English, French, Indian, Peruvian and South African arcs, in all more than five-sixths of a quadrant and containing 40 latitude stations. This calculation was revised in 1866 on account of slight changes in the data due to a careful comparison of the different standards of measure, and gave the following results as the most probable elements of the spheroid:

$a_1 =$	6 378 294 mtrs	$=$	20 926 350 Eng. ft.
$a_2 =$	6 376 350 "	$=$	20 919 972 "
$b =$	6 356 068 "	$=$	20 853 429 "
$q_1 =$	10 001 553 "	$f_1 =$	$\frac{1}{287.0}$
$q_2 =$	10 000 024 "	$f_2 =$	$\frac{1}{314.4}$
Q $=$	10 017 475 "	F $=$	$\frac{1}{3281}$

Long. of $q_1 = 15° 34'$ East.

The equator is here more elliptical than in Schubert's ellipsoid while the greatest meridian lies 25° farther west, passing through Scandinavia, Germany, Italy, Africa, the Pacific Ocean and Behrings Straits. The least meridian coincides nearly with that of Washington. The data entering these elements are the same as for the Clarke spheroid of 1866; in fact, by a slight change in the equations, equivalent to making $a_1 = a_2 = a$, the ellipsoid may be rendered a spheroid, and the elements of the latter also deduced.

In 1878, Clarke published the results of a third discussion in which the above-described data were augmented by a new meridian arc of 20° in India and by several arcs of longitude. The solution of 51 equations gave the following:

$a_1 =$	6 378 209 meters	$=$	20 926 629 feet
$a_2 =$	6 376 202 "	$=$	20 925 105 "
$b =$	6 356 076 "	$=$	20 854 477 "
$q_1 =$	10 001 867 "	$f_1 =$	$\frac{1}{290}$
$q_2 =$	10 001 507 "	$f_2 =$	$\frac{1}{296.3}$
Q $=$	10 018 770 "	F $=$	$\frac{1}{13706}$

Long. of $q_1 = 8° 15'$ West.

The equator is here less elliptical. The greatest meridian passes through Ireland, Western Africa, between Australia and New Zealand and through Alaska, while the least meridian passes through Central Asia and Central North America.

At the present time it seems to be the prevailing opinion that satisfactory elements of an ellipsoid to represent the earth cannot be obtained, until geodetic surveys shall have furnished more and better data than are now available, and particularly data from arcs of longitude. The ellipticities of the meridians differ so slightly that measurements in their direction alone will, probably, be insufficient to determine, with much precision, the form of the equator and parallels. In Europe, several longitude arcs will soon be available, and, perhaps, fifty years hence the primary triangulation of our Coast and Geodetic Survey may extend from the Atlantic to the Pacific. If it then be thought desirable to represent the earth by an ellipsoid with three unequal axes rather than by a spheroid, its elements can be determined with some satisfaction. At present the ellipsoids represent the figure of the earth as a whole very little better than do the spheroids, although, for certain small portions, they may have a closer accordance. For instance, the average probable error of a plumb line deviation from the normals to the Clarke ellipsoid of 1866 is 1″.35, while for the spheroid derived from the same data it is 1″.42. Further, the marked differences in the ellipticities of the equator of the two Clarke ellipsoids, due to comparatively slight differences in data, are not pleasant to observe. And, lastly, the ellipsoid is a more inconvenient figure to use in calculations than the spheroid. For these reasons the earth has not yet been regarded as an ellipsoid in practical engineering computations, and it is not

probable that it will be for a very long time to come.

IV.—The Earth as an Ovaloid.

In a spherical, spheroidal or ellipsoidal earth the northern and southern hemispheres are symmetrical, that is to say, a plane parallel to the equator, at any south latitude, cuts from the earth a figure exactly equal and similar to that made by such a plane at the same north latitude. The reasons for assuming this symmetry seem to have been three: first, a conviction that a homogeneous fluid globe, and hence perhaps the surface of the waters of the earth, must assume such a form under the action of the forces of gravity and centripity; secondly, ignorance and doubt of any causes that would tend to make the hemispheres unequal; and thirdly, an inclination to adopt the simplest figure so that the labor of investigation and calculation might be rendered as easy as possible. The first of these is perhaps an excellent reason, considered by itself alone, but when we begin to speculate about the probability of any regular law in the density of the earth, and further when we find plumb-line deviations only to be reconciled on supposition of non-homogeniety, it seems to assume more the nature of a rough analogy. The last is a perfectly proper reason when viewed from an engineering point of view, for where practical calculations are to be made they should be so conducted that the desired results may be obtained at a minimum cost; and this argument will always, more or less, affect even the most abstruse scientists in whose investigations there is perhaps no thought of practical utility. The second reason is not so valid to-day as it was a century ago, for gradually there have come into men's minds a great many thoughts which now lead us to suppose that there are several causes that tend to make the southern hemisphere greater than the northern. These thoughts embrace a vast field of inquiry and speculation in astronomy, physics and geology; but we can here only briefly hint at two or three of the principal facts and conclusions.

The earth moves each year in an ellipse, the sun being in one of the foci, and revolves each day about an axis, inclined some 66½° to the plane of that orbit. When this axis is perpendicular to a line drawn from the center of the sun to that of the earth occur the vernal and autumnal equinoxes, and at points equally removed from these are the summer and winter solstices. For many centuries the earth's orbit has been so situated in the ecliptic plane, that the perihelion, or nearest point to the sun, has nearly coincided with the winter solstice of the northern hemisphere and the summer solstice of the southern hemisphere. The consequences are: first, that the winter, or the space of time from equinox to equinox, is about eight days longer in the southern hemisphere than in the northern; secondly, that during the year the southern has about 170 more hours of night than of day, while the northern has about 170 more hours of day than of night; and, thirdly, that the winter of the north pole occurs when the sun is at his least distance from the earth, and that of the south pole when he is at his greatest. From these three reasons it would seem that the amounts of heat at present annually received by the two hemispheres should be unequal, the northern having the most and the southern the least. Now, when we glance at the geography and meteorology of the globe, these two facts are seen: first, that fully three-fourths of the land is in the northern hemisphere clustered about the north pole, while the waters are collected in the southern; and secondly, that the south pole is enveloped and surrounded by ice to a far greater extent than the northern. There is then a considerable degree of probability that some connection exists between these astronomical and terrestrial phenomena, that the former, indeed, may be the cause of the latter. The lower annual temperature of the earth's southern hemisphere during so many centuries may have caused an accumulation of ice and snow whose attraction is sufficient to drag the waters toward it, thus leaving dry the northern lands and drowning the southern with great oceans. Perhaps also the sun's attraction may help to accumulate the waters there. It is hence somewhat probable that there are causes tending to render the earth ovaloidal or egg-like in shape, the large end being at the south and the small at the north.

The process of finding the dimensions

of an ovaloid of revolution to represent the form of the earth would be essentially the same as that already described for the spheroid and ellipsoid. First, the equation of an oval should be stated and, preferably, one that by the vanishing of a certain constant reduces to an ellipse. From this equation an expression for the length of an arc of north and south latitude can be deduced, and this be finally expressed in terms of the small deviations between the plumb lines and the normals to the ovaloidal meridian section at the latitude stations. The solution of these equations by the method of least squares will give the most probable values of the constants, determining the size and shape of the oval due to the data employed. Such computations have not yet been undertaken on account of the lack of sufficient data from geodetic surveys in the southern hemisphere. Since such surveys can only be executed on the continents and largest islands, it is clear that such data will always be few in number compared with those from the northern hemisphere. Pendulum observations, discussed on the hypothesis of a spheroidal globe, by Clairaut's theorem, are able, however, to give some information concerning it, but, unfortunately, the number of these thus far made south of the equator is not sufficiently large to render them of much value in the investigation. It is probable that in years to come pendulum observations, or other methods for measuring the intensity of gravity, will be more employed than they are at present; and since they can be made on small islands as well as on the main lands, it is possible thereby to obtain knowledge concerning the separate ellipticities of the two hemispheres.

An important idea to be noted in this branch of our subject, is that the surface of the waters of the earth is, probably, not fixed but variable. About the year 1250, the perihelion and the northern winter solstice coincided, and the excess in annual heat imparted to the northern hemisphere was near its maximum. Since that date they have been slowly separating and are now nearly eleven degrees apart. This separation increases annually by about 61″.75, so that in the year 11700, or thereabouts, the perihelion will coincide with the southern winter solstice. Then the condition of things will be exactly reversed; the northern hemisphere will receive less heat than the southern, and if to such a degree as we have conjectured above, then the ice will accumulate around the north pole, the waters will flow back from the south to the north, the lands in the northern hemisphere become submerged while those in the southern are left dry. The change will be so slow that during no single century will it be scarcely measurable, yet it may be sufficient to alter the values of the northern quadrants by one or two kilometers. The period of a complete cycle is about 20,900 years, so that in the year 22150, of the Gregorian calendar, conditions will exist similar to those in 1250. Long before that time it is not improbable that civilization will disappear and a cloud of intellectual darkness settle over mankind. Possible enough, too, is it that in that remote age, as in the two centuries following the year 1250, men may waken out of their mental stupor and begin to make feeble inquiries about the size and shape of the earth on which it is their destiny to dwell.

V.—The Earth as a Geoid.

The word Geoid is used to designate the actual figure of the surface of the waters of the earth. The sphere, the spheroid, the ellipsoid, the ovaloid, and many other geometrical figures may be, to a less or greater degree, sufficient practical approximations to the geoidal or earthlike shape, yet no such assumed form can be found to represent it with precision. The geoid, then, is an irregular figure peculiar to our planet; so irregular, indeed, that some have irreverently likened it unto a potato; and yet a figure whose form may be said to be subject to fixed physical laws, if only the fundamental idea implied in the name be first clearly and mathematically defined.

The first definition is, that the surface of the geoid at any point is perpendicular to the direction of the force of gravity, as indicated by the plumb line at that point. From the laws of hydrostatics it is evident that the free surface of all waters in equilibrium must be parallel to that of the geoid; and the second definition determines that our geoidal surface to be investigated is that coinciding with the surface of the great oceans, leaving

out of consideration the effects of ebb and flood, currents and climate, wind and weather. Under the continents and islands this surface may be conceived to be produced so that it shall be at every point perpendicular to the plumb-line directions. If a tunnel be driven exactly on this surface from ocean to ocean it is evident that the water flowing from each would attain equilibrium therein, and its level finally show the form of the geoid along that section of the earth.

To obtain a clearer idea of the properties of the geoid, let us consider again the meridian arc measured by the United States Coast Survey in New England, and particularly the following values of the latitudes at the latitude stations:

Stations.	Astronomical Latitudes.			Geodetic Latitudes.			Diff.
	°	′	″	°	′	″	″
Farmington ..	44	40	12.06	44	40	14.31	+2.25
Sebattis	44	8	37.60	44	8	36.68	−0.92
Independence.	43	45	34.43	43	45	32.47	−1.96
Agamenticus .	43	13	24.98	43	13	23.16	−1.82
Thompson....	42	36	38.28	42	36	40.24	+1.96
Manomet.....	41	55	35.33	41	55	36.77	+1.44
Nantucket....	41	17	32.86	41	17	33.66	+0.80

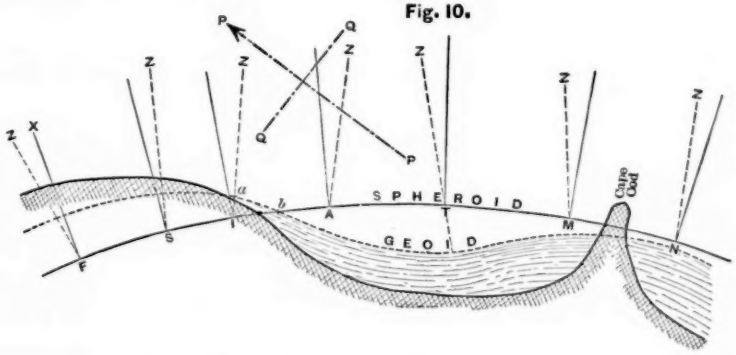
The column headed astronomical latitudes contains the values observed—that is, the angles included between a line parallel to the earth's equator and the plumb line directions at each point; while the other column contains the geodetic latitudes—that is, the angles included between a line parallel to the earth's equator and the normals to a Bessel spheroid, as computed by the use of the triangulation. The plumb-line directions as given by the geodetic latitudes are hence normal to the spheroid, while those as shown by the observed astronomical latitudes are normal to the geoid. The differences of these two, as noted in the last column, are the same as the angles between the two normals, and indicate the relative plumb-line deflections at the stations. The following figure shows on a small scale the general trend of the coast, the position of the latitude stations and the meridian arc. It might, perhaps, be expected in advance that the actual directions of the plumb lines at these points would deviate northwestwardly from the normals to a spheroid for two reasons: first, because of the heavier continent lying north and west; and secondly, because of the lighter waters lying south and east. To judge concerning this, let us imagine a section of the earth and the spheroid and the geoid along the meridian arc. Let F be a point on this meridian having the same

Fig. 9.

latitude as Farmington, S a point having the same latitude as Sebattis, and similarly for the other stations, and let us consider that the plumb-line directions at these points are the same as at the latitude stations themselves, as far at least as north and south deviations are concerned. Draw, as in the next figure, an arc of an ellipse FSIATMN to represent a section of the spheroid along the meridian arc, and let the distances FS, SI, etc., be laid off to scale equal to the distances as found from the base line and triangulation (and which are given in the last lecture). Draw at these points the normals to the ellipse; these will make with QQ, parallel to the earth's equator,

angles equal to the above geodetic latitudes. At F draw a line FZ making with QQ an angle equal to the observed astronomical latitude, so that SFX represents 2″.25, the plumb-line deviation at F. Draw at each of the other points similar broken lines, each of which must indicate the direction of the true zenith Z of its respective station. Now, the surface of the Atlantic ocean coincides with that of the geoid; let there, then, be drawn in the plane of the section a broken curved line perpendicular to the true plumb-line directions to represent this surface and let it be produced under the continent according to the same law. The figure now exhibits roughly the probable approximate relative positions of the spheroid and the geoid along this meridian arc, and a careful study of it will be advantageous in enabling us to clearly perceive some of the principal

Fig. 10.



properties of the geoidal surface. We observe that under the continents it tends to arise higher, while on the seas it tends to sink lower than the surface of a spheroid of equal volume. (But probably never is it convex toward the earth's center as indicated in the exaggerated drawing.) The reason of this is easy to see when we regard the geoid as a figure formed under the action of the attractive force of the matter of the globe. The attraction of the heavier and higher continents lifts, so to speak, the geoidal surface upward, while the lower and lighter ocean basins allows it to sink downward toward the earth's center. But the figure also shows that this rule has its exceptions; the true vertical or plumb-line direction at Farmington, for instance, inclines to the northward of the zenith of the normal to the spheroid instead of southward, as we perhaps might expect it to do. Such anomalies are, in fact, very frequent, and from them we conclude that the earth's crust is of quite variable density, and that this causes the apparent irregularities in the directions of the force of gravity in neighboring localities.

We may now also see that what we have called plumb-line deflections are really something artificial, depending upon the use of a particular spheroid. The geoid is an actual existing thing, the spheroid is not, but is largely an assumption introduced for practical and approximate purposes. At the station F, in the above figure 10, the direction FZ is the only one that can be observed, and the angle made by it with QQ has been measured with a probable error of less than one-tenth of a second of arc. The angle ZFX, or the so-called plumb-line deflection at F, will hence vary with the elements of the particular spheroid employed, and with the correct orientation of geoid and spheroid. A geodetic latitude is something that cannot be directly measured, and therefore it seems that the plumb-line deviations for even a particular spheroid cannot be absolutely found until observations have been made over an extent of country wide enough to enable us to judge of the laws governing the geoid itself. A very slight change in the position of the above elliptical arc may add or substract a constant quantity from each of the angles between the true

verticals and the normals. The differences of the plumb-line deflections at neighboring stations will, however, always remain the same. For instance, at T and M the excesses of astronomical over geodetic latitudes are 1″.96 and 1′.44, whose difference is 0″.52; but the spheroid may also be drawn giving 1″.66 and 1″.14 for these deviations and their difference is likewise 0″.52. Strictly speaking, then, it is not the plumb line which deflects, but it is the normal to an artificial spheroid or ellipsoid which deviates from the constant plumb-line direction.

Compared with a spheroid of equal volume, our geoid has a very irregular surface, now rising above that of the spheroid, now falling below it, and ever changing the law of its curvature, so as to conform to the varying intensity and direction of the forces of gravity. Where the earth's crust is of most density and thickness there it rises, where the crust is of least density and thickness there it sinks. From a scientific point of view it will be valuable to know the laws governing its form and size; from a practical point of view it appears that until these are known the earth's figure can never be accurately represented by a sphere or spheroid or ellipsoid, or other geometrical form. For instance, if it be desired to represent the earth by an oblate spheroid, the best and most satisfactory one must be that having an equal volume with the geoid, and whose surface everywhere approaches as nearly as possible to the geoidal surface. This latter condition may be mathematically expressed by saying that the sum of the elevations and depressions between the two surfaces shall be a minimum. Such a spheroid cannot, of course, be found until more and better data concerning the geoid have accumulated, yet what has already been said is sufficient to indicate that the dimensions at present used are probably somewhat too large. Granting that in general the geoid rises above this spheroid under the continents and falls below it on the seas it seems evident, since the area of the oceans is nearly three times that of the lands, that the intersection of the two surfaces will always be some distance seaward from the coast line (as seen at *b* in Fig. 10). Now geodetic surveys can only be executed on the continents, and even if they be reduced to the sea level at the coast (*a* in Fig. 10), the elements of a spheroid deduced from them will be too large to satisfy the above condition of equality of volumes (for the ellipse through *a* is evidently larger than that through *b*). At present it would be almost a guess to state what quantity should be subtracted from the semi-axes of the Clarke spheroid on account of these considerations; but there are reasons for thinking that 1,000 meters would be too much.

We have now to briefly consider the important question, how can the shape and size of our geoid, and its position with reference to the earth's axis of rotation, be determined? From what has already been said, it is not difficult to conclude that a fair mental picture of its surface may be acquired for a locality where precise geodetic surveys have been executed. At points along the coast let the sea level be determined as due to the earth's attraction alone, the effect of tides, currents and storms being eliminated. These are points on the geoidal surface, and it may be imagined to be produced inland, so that everywhere it shall be perpendicular to the direction of the force of gravity. To obtain numerical data regarding its form and position, it may referred to the surface of a spheroid, the direction and amount of the plumb-line deflections indicating always its change of curvature and its relative elevation or depression as compared with the spheroid. But on the oceans, where geodetic operations cannot be executed, it will, probably, ever be impossible to obtain such numerical results. At the present time there is very little known regarding the actual figure of the geoid even on the continents. The word Geoid, in fact, with all the fruitful ideas therein implied, is not yet ten years old, and in all relating to it theory is in advance of practice. Bruns, for instance, has demonstrated that the mathematical figure of the earth may be determined independently of any hypothetical assumption concerning the law of its formation, provided that there have been observed at and between numerous stations five classes of data, namely, astronomical determinations of latitude, longitude and azimuth, base line and triangulation measurements, vertical angles between

stations, spirit leveling between stations, and determinations of the intensity of the forces of gravity. These five classes are sufficient for the solution of the problem, but also necessary, that is, if one of them does not exist, a hypothesis must be made concerning the shape of the earth's figure. These complete data have, however, never yet been observed for even an extent of country so small as England, a land probably more thoroughly surveyed than any other. To render geodetic results of the greatest scientific value, it is hence necessary that either the pendulum, or some instrument like Siemens' bathometer, should be employed to determine the relative intensity of the forces of gravity at the principal triangulation stations, and that trigonometric leveling, by vertical angles, should be brought to greater perfection. But years and centuries must roll away before sufficient data shall have accumulated to render a theoretical discussion possible and satisfactory.

In conclusion, it will be well to note that our geoid is not a fixed and constant figure. Upon the earth men build towns and cause ships and trains to glide; simultaneously with these movements of matter wrinkles and waves appear in the geoidal surface. But the changes that man can effect are infinitesimal in comparison with those produced by nature. The atmospheric elements are continually at work to tear down the continents and fill up the ocean basins; ever conforming to such alterations the geoid tends to nearer and nearer uniformity of curvature. Internal fires cause parts of the earth's crust to slowly rise or fall, and immediately the geoidal surface undergoes a like alteration. As the center of gravity of the earth oscillates north and south during the long apsidial cycle of 20,900 years, the position and shape of the geoid will vary slowly with it. Perhaps also the axis of rotation of the earth may not be invariable with respect to its mass but subject to slight oscillations. The changes produced by these causes are not all so minute as to escape detection, for already small but measurable variations have been discovered in the latitudes of several of the oldest observatories, and we may expect that in future centuries other alterations still will be noticed and observed and discussed. When the laws governing these changes shall have become understood, it will be possible to reason more accurately than now concerning the past history and future destiny of our earth.

THE PANAMA CANAL.

By Captain BEDFORD PIM, R. N., M. P.

From "Journal of the Society of Arts."

PART I.

INTRODUCTION.

AGAIN we have the project of inter-oceanic communication between the Atlantic and Pacific brought before the world; this time in a manner which is calculated to arrest the attention and stimulate the energy of those interested, for has it not been introduced by one whose name is a household word in connection with the great work of his life, the Suez Canal? Need I say that I refer to M. le Comte Ferdinand de Lesseps.

THE PARIS CONGRESS.

The mode adopted to give prominence to the desired enterprise, of opening the American Isthmus, was by calling a Congress at Paris to adopt the best route. Such a Congress was accordingly convened under the auspices of the French Geographical Society and M. de Lesseps, and held its sittings from the 15th till the 28th of May of this year (1879).

At first sight, this would seem to have been an admirable plan to call attention to the project, and insure a practical result, but, unfortunately, Congresses, like Departmental Committees, are neither infallible nor even independent, and the selection of a route for the proposed canal seems to have been a foregone conclusion.

PANAMA SELECTED.

The line chosen was parallel, as near as possible, to that of the Panama rail-

way, and was voted for by a great majority, as the following extract from the report of Admiral Ammen to the United States Government will show:

"At 1.30 [on the 28th of May, 1879] the final full meeting of the Congress took place, the report, *résumé*, and resolution were read, and the yeas and nays taken upon the latter, resulting in a vote or abstention of 99 members out of 135, as given in the list—seventy-five voting yes, eight no, and sixteen abstaining. The character of the voters and of those who absented themselves will appear in the report of Civil Engineer Menocal. I abstained from voting on the ground that only able engineers can form an opinion after careful study of what is actually possible, and what is relatively economical, in the construction of a ship canal.

"The text of the resolution is as follows:

"'Le Congrès estime que le percement d'un canal interoceanique à niveau constant, si désirable dans l'interêt du commerce et de la navigation, est possible, et que le canal maritime, pour répondre aux facilités indispensables, d'acces et d'utilization que doit offrir avant tout un passage de ce genre, devra être dirigé du Golfe de Limon à la baie de Panama.'

"The hall was densely crowded, many ladies being present; about one hundred members or delegates, and three to four hundred other persons. Whenever a vote of 'yes' was given, especially by some one who had more or less opposed the conclusion, a very enthusiastic clapping of hands occurred, which would hardly have been the case had the audience regarded the selection as depending wholly on natural conditions or advantages, or on physical causes. The Congress then adjourned."

M. DE LESSEPS.

It is impossible to disguise from oneself that the strong and very natural personal feeling of the members of the Congress towards M. de Lesseps was allowed to override a strict practical dealing with the subject, which alone could command the respect and adhesion of the public.

Strangely enough those most deeply concerned seem either to have taken but little interest in the proceedings, or to have been left out in the calculation vulgarly called "counting noses." Be that as it may, the practical result of the Congress amounts to this, that a "Panama Canal" was voted, and its execution entrusted to M. de Lesseps. The United States, through their official delegate, Admiral Ammen, did not approve of such a decision, preferring, for very substantial reasons, the route by way of the River San Juan and the lakes of Nicaragua.

AMERICAN, ENGLISH, AND FRENCH INTERESTS.

In discussing the subject of interoceanic communication between the Atlantic and the Pacific Oceans, it is very necessary to ask ourselves the question, "Who are those interested?"

Now, I have given this matter very serious consideration, and I have come to the conclusion that, while it is true that every nation under the sun may claim to have an interest in the international work of piercing the isthmus of the New World, if only from a sentimental point of view, yet, practically, the success of the undertaking depends upon three parties.

Of these parties, first and foremost stand, of course, the American States. I do not mean the United States, but all the States of America. Secondly, England; and thirdly France, though in a minor degree, and simply because she has possessions in the West Indies, and has long been desirous of extending her commerce across the isthmus into the Pacific.

These three nations, then, are "those interested," upon whom will devolve the risk and expense of an undertaking, which it cannot be denied, must be one of very considerable proportions.

HOW REPRESENTED AT CONGRESS.

Let us see how these interests were represented at the Paris Congress; and, first, as regards France, I think it may fairly be said that it would have been impossible to find a better representative than M. de Lesseps. I will even go a step further, and say that it would have been more satisfactory if M. de Lesseps, in the first instance, had embodied the Congress in his own proper person, and exercised his great practical intelligence without seeking the uncertain and heter-

ogeneous assistance of a Congress at all. England was not officially represented, although it is quite true that Colonel Stokes was announced as our delegate. Upon writing, however, to the Foreign-office on the subject, I received the following reply, which settles the matter, and correctly measures the interests taken by our Government:

LETTER FROM FOREIGN OFFICE TO CAPTAIN PIM.

"Foreign office, May 8th, 1879.

"SIR:—Lord Salisbury has desired me to acknowledge the receipt of your letter of the 3rd inst., inquiring whether it is true that three delegates have been appointed by her Majesty's Government to attend the Conference at Paris on Interoceanic Transit across Central America.

"In reply, I am to inform you that no delegate has been officially named to represent this country, but that Sir John Stokes has been invited by M. de Lesseps to attend the Conference, and he has received the permission of the Government to accept the invitation.

"I am, sir, your obedient servant,

(Signed) PHILIP CURRIE.

"Captain Bedford Pim, M.P."

In respect to the United States, not only was a representative appointed in the person of a distinguished officer of the Navy, Rear-Admiral Daniel Ammen, assisted by Anecito G. Menocal, Esq., Civil Engineer of the United States Navy, but particular instructions were given to the Admiral for his guidance in the important mission with which his Government had entrusted him.

The following is a copy of the instructions given to Admiral Ammen; they are of value in this connection as showing the very natural interests taken by the Government of the United States in any project for piercing the isthmus of their country:

ADMIRAL AMMEN'S INSTRUCTIONS.

MR. EVARTS TO ADMIRAL AMMEN.

"Department of State,

"Washington, April 19th, 1879.

"Rear-Admiral Daniel Ammen, U.S.N.,

"Washington, D.C.

"SIR:—The President having appointed you to be a Commissioner on behalf of the United States, to attend an International Conference to assemble at Paris, on the 5th of May proximo, under the auspices of the Geographical Society of Paris, for the purpose of considering the various prospects of an international canal across the American Isthmus, I have the honor to acquaint you officially with the fact of such appointment. It is also incumbent upon me to give you certain instructions for your guidance, in the execution of the President's wishes. The importance and magnitude of the projected enterprise are such as to command earnest attention, especially on the part of those countries whose trade is to be affected in a marked degree by the success or failure of the scheme.

"This Government, in the interest of its rapidly growing commerce, not only between its own Atlantic and Pacific shores, but with the other American States on the western coast of the Continent deems it advisable to keep itself well informed on the subjects, and also to give any useful information in relation thereto to other governments interested in the scheme of inter-oceanic communication.

"You are accordingly instructed to attend the Conference of the International Commission concerning the opening of an interoceanic canal through the American Isthmus, to be held at Paris next month, and you will be expected to carefully watch its progress and results, and report them to your Government.

"You will take part in the discussions of the Conference, and will communicate such scientific, geographical, mathematical, or other information as you may possess, and as is desired or deemed important. In this work you will be assisted by Civil Engineer Anecito G. Menocal of the United States Navy, who has been detailed and appointed a Commissioner for the purpose with like powers. You will, however, have no official powers o diplomatic functions.

"You will hold no official communication with the officers of the French Government, except such as may, by virtue of their connection with the French Geographical Society, or as delegates, *ad hoc*, take part in the proceedings of the Conference. You are not authorized to state what will be the decision of the Government of the United States in regard to

the points involved or the line of action it will pursue.

"The Conference is understood to be, not one of diplomatic representations of the respective governments, but rather a gathering of scientific men and public officers, whose experiences render it desirable that they should have an opportunity for the exchange of information and of views. Your well-known wide acquaintance with the subject proposed to be discussed makes it peculiarly fitting that you should be selected to meet other distinguished engineers and officers who have given like attention to the matter.

"You are furnished herewith with such documents and records as the files of this and other departments contain, that may be of interest and importance.

"Your own familiarity with the subject, and careful study of it in all its bearings, render it unnecessary to give you further instructions on this point.

"I am, sir,

"Your obedient servant,

"WILLIAM M. EVARTS."

These instructions sufficiently attest the interest attached by the United States to the canalization of the American Isthmus, which is also manifest by the light of subsequent events; still no attempt whatever has been made to embarrass in the slightest degree the movements of M. de Lesseps, although means have been taken to make it known that the route which will be favored by the United States is not that selected at the Paris Congress; on the contrary, the scheme of M. de Lesseps will be avoided altogether, and the canal built, if anywhere, through Nicaragua, although the exact direction will not be decided upon without further surveys and lines of new levels.

Upon this point, and to show the steps already taken by our energetic cousins across the Atlantic, I beg to call your attention to an extract from the *Times* of the 4th October last.

The following is General Grant's letter to Admiral Ammen, in which he consents to the latter's request to take the presidency of the proposed Nicaragua Canal Company:

"TOKIO, Japan, August 19.

"*My Dear Admiral:* Your letter of the 2d of July reached me a few days since. After two days reflection of the part I should take or consent to take—if offered—in the matter of the interoceanic canal, *via* Nicaragua, I telegraphed to the Secretary of the Navy at Washington: 'Tell Ammen I approve.—Grant.' I hope you received the despatch. On the 27th, two weeks after this leaves Yokohama, we sail for San Francisco. I do not feel half so anxious to get home as I did eighteen months ago. There is no country which I have visited, however, this side of Europe, except Japan, where I would care to stay longer than to see the points of greatest interest. But Japan is a most interesting country, and the people are quite as much so. The changes that have taken place here are more like a dream than a reality. They have a public school system extending over the whole empire and affording facilities for a common school education to every child, male and female. They have a military and a naval academy which compare well with ours in the course taught, the discipline, and the attainments of the students. They have colleges at several places in the empire on the same basis of instruction as our best institutions. They have a school of science which I do not believe can be surpassed in any country. Already the great majority of their professors—even those engaged in teaching European languages—are natives, most of them educated in the very institutions where they are now teaching.

"But I hope to meet you soon, and then I will say more on this subject than I care to write in the limit of a letter.

"Mrs. Grant sends her love to Mrs. Ammen and the children. Please remember me kindly also.

"Yours truly, U. S. GRANT.

"Admiral D. Ammen."

RESUME.

This, then, is the position of affairs. Through the influence of M. de Lesseps, a Congress was convened, and met at Paris in May last. It consisted of 135 members, and the result of its action was a vote of confidence in M. de Lesseps, and his favorite plan, as embodied in the following resolution, was carried by ayes, 75; noes, 8; not voting, 16; absent, 36.

"The Congress considers that the cutting of an interoceanic canal at the sea

level, so desirable in the interests of commerce and navigation, is possible, and that a maritime canal, to afford those indispensable facilities of access and utility which such a passage must, above all things, possess, should be carried from the Gulf of Limon to the Bay of Panama."

A canal, *à niveau constant*, at the sea level, and without locks, is no doubt the most desirable mode of joining together two oceans. No process can be more simple, if only the intervening land is level and below the level, as at Suez (M. de Lesseps' model work), and there is besides every advantage in the shape of climate, abundance of labor, and the ease with which labor-saving appliances can be used; but it is a very different affair when the reverse is the case, and, moreover, the harbor accommodation at either end is, to use a mild term, indifferent. From these causes alone the work of opening a canal between the Atlantic and Pacific across the Isthmus of Darien or Panama assumes gigantic proportions, and bears about the same proportion to that at Suez as the excavation of Mount Cenis to the boring of a tunnel under the Thames to-day. It is not, therefore, to be wondered at that adverse criticisms were leveled at M. de Lesseps' scheme, even before the breath was out of the body of the Congress; and, that the subsequent growth of such criticisms has had the effect of staying his proceedings, so that at present the scheme of cutting a canal, *a niveau constant*, on a line parallel to that of the Panama railway, is in abeyance.

Indeed, the project is not likely to be revived, for independently of the difficulties I have mentioned, the locality is not adapted for the purpose in view, owing to the persistent calms which effectually bar the approaches to sailing ships, and vex the navigation beyond endurance.

I have had long experience of the physical geography of Central America, and the Bay of Panama in particular. On one occasion, the frigate *Herald*, in which I was serving, was towed by H. M. S. *Sampson* 700 miles off the land before picking up the slightest breeze; but although my practical experience on both sides of the isthmus happens to be very extensive, I will not on this occasion rely upon it, but call your attention to a letter bearing on the subject, addressed to me from my old friend, the late Commodore M. F. Maury, LL.D., familiarly known to us—I may truly say to all the world—as the author of that charming work, "The Physical Geography of the Sea." His name is a household word as the greatest authority on this subject, not only among his own countrymen in the United States, but quite as much with us Englishmen. His letter is dated as far back as July, 1866, and I am sure the members of the Society of Arts will have much pleasure in seeing it published in full in their *Journal*, as a most important contribution to our scientific knowledge of the Isthmus of the New World.

Commodore Maury tells us in the plainest language that "If nature, by one of her convulsions, should rend the Continent of America in twain, and make a channel across the Isthmus of Panama or Darien, as deep and as wide and as free as the Straits of Dover, it would never become a commercial thoroughfare for sailing vessels." I have only to endorse this opinion, for, of all parts of the world I have ever visited, the calms which prevail in the Bay of Panama are the most vexatious and enduring.

It is, therefore, by no means surprising that M. de Lesseps is taking time to reconsider his position, and, from what I know of that gentleman's character, I hope and believe that such consideration will be so shaped that his genius, his experience, and his wonderful energy and perseverance will, under no circumstances, be lost to those who seek the junction of the Atlantic and Pacific, no matter by what route, or whether at the sea level, or with or without locks.

The following is the late Commodore Maury's letter on the physical geography of Panama and Nicaragua:

My Dear Captain Pim: I had occasion some years ago to study, more or less closely, almost every route between the British possessions on the north and the Isthmus of Darien on the south, whether for rail or canal, that had up to that time been attempted or projected across the American continent.

Owing to the character of the researches with which I have been for more than twenty years engaged, my attention was directed to those routes rather in

their physical and commercial aspects, than to their topographical features, or to their facilities of construction.

The great importance of one or more good commercial highways across Central America being admitted, the whole question as to route resolves itself pretty much into a question of the cost of construction, and the facilities of ingress and egress by sea, to and from the opposite termini; the latter is an affair of winds and currents. Their influence is powerful. Panama has the advantage in shortness of land transit; Nicaragua has the advantage in winds, terminal ports and climate. The first is obvious: but to place the latter in a clear light, a little explanation may be necessary.

To make this explanation clear, let us, with Panama as a center, take a general survey of the winds as they prevail in the Pacific ocean.

As a rule, the prevailing winds in all that belt of ocean extending from the parallel of 35° north down to the parallel of 35° south, are from the eastward. This belt is 70° of latitude broad; in it are included the bands of the northeast and south-east trade winds, and the belt of equatorial calms; the latter separates the two systems of trades, and extends all the way across the Pacific.

Looking westward, therefore, from Panama towards the islands of the Pacific, or towards Australia, China or Japan, you observe that Panama is directly to windward of them all—and that, therefore, whilst the commercial routes from Panama to any of these places are all down hill, or to leeward, the way back is up hill, to windward (for over this broad band of the ocean easterly winds blow all the year, except now and then, when they are interrupted for a short time by the monsoons). Still, by making a detour, the return voyage to Panama would not be so difficult as from this statement it would appear to be, were it not for other physical conditions which stand in the way of navigation.

I have spoken of a calm belt about the equator; Panama is within its range. Owing to the contour of the central American isthmus, the height and direction of the mountain ranges by which it is traversed, and the influence of these upon winds, this calm belt is greatly enlarged on the Pacific or lee side of the Isthmus.

It is difficult to convey to one who has never experienced these calms, an idea of the obstinacy with which they vex navigation. We are all familiar with calms at sea, which last for a few hours, or even a day, but here they last for days and weeks at a time. I have known vessels going to or from Panama to be detained by them for months at a time. An American sloop-of-war, bound from Mazatlan, in Mexico, to Callao, in Peru, once attempted to make a short cut by running down the coast. She finally succeeded in passing these Panama calms, but she was delayed and baffled by them and the adverse currents from the south, until her provisions fell short, and she had to put into Payta to avoid starvation. The Humbolt current, which skirts the coast of South America all the way from Cape Horn, is felt in the offings of Panama.

The Gallapagos Islands, a fine and fertile group, are within the influence both of this current and of these calms; they are about 600 miles from Panama and about 500 from the South American coast; they tell, in their mute way, a curious story about these calms. Though so near the Continent of America, they are the only islands in that wide ocean capable of sustaining a population, that were uninhabited when discovered. The reason is to be found in these calms; and simply because the wind there never blows continuously enough to waft a canoe from any quarter upon their shores.

On one occasion the British admiralty, wishing to send one of their sailing vessels into the Arctic Ocean from Panama in time to save the season, had her towed by a steamer through the calm belt, and carried 700 miles out to sea before she could find a breeze.*

Panama is not in the center of this calm belt; it is to the north of the center, and consequently a sailing vessel, by shaping her course directly south from Panama, would, though bound for Peru or Chili, not only have to encounter the force of the Humboldt current, feeble though it be, but she would get into the thick of these

* H. M. S. *Herald*, in which ship Captain Pim was then serving.

"doldrums;" she must, therefore, to avoid them, be content to run along to the westward for upwards of 200 miles until she approaches the coast of Costa Rica. Here the coast-line trends off to the northward and westward; she follows it, reaching the latitude of Realejo before she can get fairly within the north-east trade winds, upon which she depends for gaining an offing and getting fairly out to sea. Having come up to them, she stands off to the southward and westward with flowing sheets, taking care not to cross the belt of equatorial calms within a thousand miles of Panama, nor until she can reach it in a much narrower part. Her port now lies to the southward and eastward, but she has entered the south-east trades, which are directly ahead. Consequently, she has to stand off on a bow line to the southward and westward, until she can clear these winds and get others from the west; this takes her as far south as 35°, and often beyond 40°. Here she makes her easting, taking care to bring her port so to bear, that she can fetch it with the south-east trades again. Such is the way often taken, under canvas, from Panama to Valparaiso, the "Chinchas," Calleo, and all the "Intermedios." This is a curious route, but one that is not unfrequently pursued by the cleverest navigators; it would be well, for the better understanding of these facts, to refer to the map, for in consequence of these calms (and there are no others in the world like them) you will observe that this route actually takes the ship farther beyond, or to the south of "the Chinchas," if they be her destination,—than she was to the north of them when she got under way from Panama.

Upon the rush which took place for California, in consequence of the discovery of gold there, the route at first pursued by the sailing vessels, which doubled Cape Horn, both from Europe and America, was to cross the equator in the Pacific, in about longitude 90° west. This brought them along the outer edge of the Panama region of baffling winds, and made their average voyage out, one of six months. Cases occurred on this route, in which the passengers, to avoid starvation, actually abandoned their vessel in these calms, took to their boats, and so reached land.

This continued to be the route until the investigations of the winds and currents in the Pacific (to the results of which investigations I am still speaking) enabled me to point out a better one. Captains were then advised to avoid those Panama calms, and instead of crossing the equator in the Pacific, near the meridian of 90° west, they were recommended to cross it some 25° or 33° more to the westward. They did so, and this is the favorite route under canvas now; and the passage by it, instead of requiring six months, averages four.

These remarks apply to the approach and departure by sea to or from the Pacific terminus of any route across the Isthmus of Panama or Darien, and even with greater force to the Atrato and others on the South American side of Panama. In short, the results of my investigations into the winds and currents of the sea, and their influence upon the routes of commerce, authorize the opinion which I have expressed before, and which I here repeat, namely—if nature, by one of her convulsions, should rend the Continent of America in twain, and make a channel across the Panama or Darien as deep, and as wide, and as free, as the Straits of Dover, it would never become a commercial thoroughfare for sailing vessels, saving the outward bound and those that could reach it with leading winds. Steamers would, and coasters might, use it, but homeward bound vessels in the China, India, or Australian trade, rarely.

Such, so far as the winds are concerned, are the physical difficulties in the way of a great commercial highway at the southern extremity of Central America, and which no engineering skill, however great, can overcome. I shall have occasion to refer again to the Panama route for other contrasts.

In the meanwhile, let us turn to the most northern of these Central American routes, for which subventions have been obtained.

After, and in consequence of, the discovery of gold in California, the subject of a shorter and better route than that in use—viz., the "180 day's passage," *via* Cape Horn, was discussed in commercial circles. A "gateway" to the Pacific now for the first time engaged the earnest attention both of the people and Govern-

ment of the United States. The route next in favor after that of Panama, especially in New Orleans, was that called the Tehuantepec route, having its Pacific terminus in the Gulf of that name, and its Atlantic terminus at the mouth of the Coatzacoalcos river. It had attracted the attention of Cortez—the world was familiar with the idea of a grand commercial throroughfare there. A grant with munificient franchises had already been obtained from Mexico, and a company was speedily organized with ample means, first to construct a plank-road between the head of the navigable streams on the two sides, and then a ship canal.

This route was much more attractive than the Panama Route to the people inhabiting the Mississippi Valley; Panama is nearly equi-distant from New York and New Orleans, but the Tehuantepec route would be a saving to the States bordering on the Gulf of Mexico, of no small moment both in time and distance, for its eastern terminus is almost at their door. With a strong bias in its favor, I was invited to discuss its merits. I was forced nevertheless to condemn it, and to decide, as between the two, in favor of Panama, at that time its rival in the money market and for the public patronage.

The Tehuantepec route was condemned as impracticable for two principal reasons: no engineer could be found rash enough to undertake, for any practicable sum, to build a safe harbor for its terminus on the Pacific, and deepen the water on the bar at the mouth of the Coatzacoalcos. Moreover, the violence of the "northers," for which the Gulf of Mexico is celebrated, would make the anchorage off its eastern terminus for ever unsafe at certain seasons. This route, therefore, was abandoned, although the climate, the resources on the wayside, and the distance, were all greatly in its favor. It lacked harbors.

No other route to the north of the peninsula of Yucatan has been brought to my attention.

Passing it, we leave the Gulf, and enter the waters of the Caribbean Sea, from which various routes have been projected, and several of which have been pressed with more or less zeal upon the public; none of these, however, save the several Nicaraguan routes, seem to have had merits enough to arrest the attention of capitalists, or to deserve serious consideration, except perhaps the Honduras route. Little or nothing is known about the topographical features of that route; I rather fancy a careful survey there would disclose heavy gradients and sharp curves. But, be that as it may, that route, as drawn by the pen on the chart, looks very attractive, both on account of its shortness and the harbor facilities afforded for each terminus. Its terminus on the Pacific is close to that selected for the Nicaraguan road, and is quite as commodious. But admitting the gradients to be ever so easy, and the curves few and gentle, the winds interpose an obstacle that is fatal to this route as the highway of commerce between the two oceans.

Look at the chart; you observe that the eastern terminus of this route is in the corner of the coast, forming a right angle and opening out to the north-east. The north-east trade-winds blow home here, and consequently a vessel wishing to clear from this end of the route, no matter for what port, would find herself embayed at the very outset, and under the necessity of a "dead-beat" of 400 or 500 miles, against the whole force of a head sea and the north-east trades, before she could be said to have gained an offing. This would make the passage from this end of the Honduras route to England, but little, if any, short of the homeward passage round the Cape of Good Hope, from India and China, or around Cape Horn from Australia. With this fact staring you in the face, nothing more need be said of the Honduras route until canvas is driven from the ocean by some cheaper and faster means of propulsion.

We come now to the Nicaraguan routes. Of these there are several. Though longer across from ocean to ocean than Panama, some of them have already, and with a degree of success by no means discouraging, competed with it before the world for public favor.

The Emperor of the French himself proposed and advocated the establishment of a great commercial highway across this part of the Continent. Later, M. Belly, adopting his idea, obtained a grant, and proposed to construct a

Nicaraguan ship canal across from sea to lake and from lake to ocean.

At first this project found favor with the Emperor. He was disposed to take it under Imperial patronage. But he was not content with a topographical survey of the route. There were other physical conditions and circumstances which that sagacious monarch knew might exercise a controlling influence over such a work. He, therefore, chose to refer it for examination by the lights which the investigations concerning the winds and currents of the sea might cast upon it, and I was also invited to give my opinion upon it, according to any other information I chanced to possess. For this purpose, M. Belly's data and arguments were all placed before me; but suffice it to say, that when the matter came to be treated in connection with the existing requirements of commerce, this canal scheme proved to be wholly impracticable at the present day, and it was consequently given up.

Another Nicaraguan transit route was started by Vanderbilt and others, of New York, in opposition to the Panama road. They "established a line across," and "put on a line of steamers" to run in connection with it between New York and California. The passengers were conveyed across partly by lake and river steamboats, partly by stage-coaches, and on mules; and yet, although they occupied two days in the transit, this route, even with such drawbacks as these, fairly divided with Panama the passenger traffic. It was finally bought off by the Panama company.

In 1849, this transit company, under the title of "The American Atlantic and Pacific Ship Canal Company," obtained a grant from Nicaragua, and entered into a contract with that State, for the construction of such a work. Eight years after, however, I find them soliciting a modification of this contract, on the ground that there was not water enough in the lakes of Nicaragua to float such ships as the canal was intended to pass. Thus the ship canal question appears to have been disposed of for the second time, and perhaps until the Pacific slopes of Mexico, California, Oregon, and Columbia shall be further subdued, and be more abundantly replenished with inhabitants.

It is through this country and near the canal route that the railroad proposed by you is to run. I have never been on the Isthmus, and know nothing of the engineering difficulties of the road, nor of the typographical features of the country, but have reason to believe that they are by no means difficult. Skillful engineers, both French and American, have examined them. Those of both nations report gradients enough for a canal. We may safely infer, therefore, that the route for your road presents no difficulties that the railway engineer need fear. Indeed, I am assured that the curves are gentle and the gradients easy. In truth, the lakes, their distance from the sea and their height above it, indicate that the summit-level is to be attained without any very steep ascents.

It is to this part of the Isthmus too, to which we must look for a route which shall best fulfill the present requirements of commerce between the two oceans, as well as of transportation and travel between the Pacific shores of North America, on the one hand, and the Atlantic shores, both of Europe and America, on the other. The ship canals have all been virtually abandoned, at least for the present, by their original projectors, and the road now proposed is required to supplement the Panama route. The south American markets are now giving the Panama route as much as it can do. English merchants have, within the last few years, put on a line of steam propellers between Panama and the coast south as far as Chili. These have given the road an enormous increase of traffic; no such increase has come from the North American side. Your road would draw it from that quarter, and vessels under canvas would, in the main, do the fetching and carrying for the Nicaragua route, which, for reasons already stated, cannot be done for Panama. The aggregate amount of this trade is immense, and it is neither accommodated for Panama, nor Panama for it. For this reason, as I have said, one route will supplement the other. One has already its chief traffic with the south coast, the other will have it with the north, the islands of the Pacific, and its western shores.

Nicaragua will also receive by canvas,

from the ports of Chili and the South, an immense amount of commerce that cannot afford to go to Panama by steam, and that never will reach it by canvas.

Moreover, though the distance, as the crow flies, from Nicaragua to Chili and Peru, is greater from Nicaragua than it is from Panama, yet the average sailing voyage is much less in time.

Your road, therefore, as a thorough fare for trade and travel with certain marts in the Pacific, may, in particular aspects, boast of important physical advantages which are wanting to Panama. Do they constitute inducements sufficient to tempt capitalists to embark in it as an investment?

This, I take it, is the real point to which you wish me to come.

The value of the franchises conceded under the grants to each route are better understood by you than by me, for I have not carefully studied either of them; and as for the relative character of the difficulties or facilities which stand in the way of the engineer or beckon him on, you require no opinion from me, even if I felt myself qualified to express one, which I do not.

Therefore, returning again to the physical features of the Panama route, as I promised to do, we can now compare more in detail than I have yet done the advantages possessed by each, as far as those advantages are influenced by facilities of navigation, by the elements, by salubrity of climate, and by the dictates of commerce.

The French and English Admiralty charts give the most accurate information that I possess concerning the harbors at the opposite ends of the two routes, Panama and Nicaragua—I mean, as to mere anchoring ground, depth of water, and shelter afforded.

It is proper to remark here that I was a great friend, an earnest advocate, and active supporter of the Panama road, giving it in 1849 the preference over all other isthmian routes. At that time my "wind and current" investigations had not extended into the Pacific Ocean; and the discovery of those causes which make the approach and departure to and from the Bay of Panama so very difficult for sailing vessels, had not been sufficiently established to give them their proper weight.

That I may make myself clear as to the obstacles which these researches, confirmed by the experience of the Panama Company themselves, have shown to be in the wap of the Panama route, I send you a chart, on which I have roughly sketched the trade-wind regions of the Pacific, the parts of the ocean where the Panama calms dominate—the deeper the shading the more vexatious the calms—and the route of vessels, trading under canvas, between Panama and the various ports in the Pacific. You will observe at a glance that the Isthmus of Panama, or Darien, is, on account of these winds and calms, in a purely commercial point of view, the "most out-of-the-way" place of any part of the Pacific coast of intertropical America.

You will observe also that the offings of Realejo are not beset with calms at all comparable for obstinacy to those which hinder navigation in the bay and offings of Panama. The reason of this is, that Realejo, instead of lying within the range of the Darien calms, lies in the regions of the "little monsoons" of Central America (N. E. trades), which, in August and September, blow from the southwest along this part of the coast. They are "soldiers'" winds for coasters in either direction, and do not extend far to seaward.

In consequence of this difference in the character of the offings of the two routes, the Pacific terminus of the Nicaraguan transit is on the wayside of the sailing voyage from Panama even to Callao and Valparaiso. You observe that the region liable to these Darien calms, extends from a little to the westward of Panama Bay, and thence along the Pacific coast, all the way to the equator It does not cross the continent, but, like a wedge with the blunt edge resting on the land, it extends far away to the west, getting narrower and narrower as it goes, and consequently more easy to cross from north to south, but more difficult to traverse from point to base or from west to east.

With this explanation, it is easy to understand how it is that sailing vessels from Panama often have to go north to get south. That also is the best way to get out to sea when bound in any other direction. Panama is in 90° N.; the distance thence to the equator is between

five and six hundred miles. Navigators look on "this passage to the Line as the most perplexing experienced in the Pacific for sailing vessels; thirty days is not considered out of the way, owing to calms, squalls, and torrents of rain which fall during these months,"* *i. e.*, in the rainy season.

H. B. M. ship *Monarch* had to be towed across the line by a screw steamer after leaving Panama and taking this route.†

"Lieutenant Maury," remarks Mr. Hull, Master of H. M. S. *Havanah*, truly says "that the passage under canvas from Panama to California is one of the most tedious, uncertain and vexatious that is known to navigators."‡

Realejo is on the northern verge of these calms, and where they have nearly ceased to be vexatious to the navigator at any season. Here then is the physical advantage in favor of the Nicaraguan route, for which it is difficult to find the money value.

Having obtained an offing from the Pacific terminus of either the Panama or Nicaraguan route, the winds are fair for all voyages, except those on the ports of South America.

But on the return voyage, the Nicaraguan Transit Terminus is again on the wayside from the islands of the Pacific, from California, British Columbia, the mouth of the Amoor, Japan, China, etc. The returning ship has to fetch a compass to the north; this brings her into the westerly winds, which prevail north of the fortieth parallel of north latitude, and lead her along the northwest coast of America. Consequently, in running it down, all such trades have to pass the shores of Nicaragua to get to Panama.

Then in coming from Australia there is a choice of routes: the sailing vessel may either run down to the south of 45° south latitude to make her easting in the westerly winds of that hemisphere, and then steer north; or she may steer north on leaving Australia, cross both systems of trades, and make her easting on the polar side of 40° north. This last route is the one recommended by the sailing directions.

As regards the line of steamers in contemplation between Panama and Australia, they can go straight enough, and have the wind quartering all the way; but returning by the same route they will have a stiff and strong breeze "right in their teeth;" and as the southeast trades are stronger than the northeast, it is probable that even the steamers, upon trial, will find it more convenient to go north about and pass the offings of Realejo on their return voyage to Panama.

But the great centers of trade to which a good commercial highway across Central America would lead and develop, lie principally in the northern and not in the southern hemisphere; and here the Nicaraguan road has greatly the advantage over Panama, by shortening the actual distance.

By the great circle, and consequently the best route for steamers between Realejo, China, Japan, etc,, British Columbia is on the wayside, and by touching at Vancouver—as it is about half way—the voyage between Realejo and Japan or China would be divided into two parts, each about equal to a voyage by steamer between Liverpool and Norfolk in Virginia.

Both of the Isthmus routes have their rainy season: that of Panama is long and trying. In Nicaragua the season is not so long, and there the rains generally come on in the afternoon, after which it clears up till the next afternoon. On the Isthmus of Panama the atmosphere is reeking with moisture, and the rain pours all the time. That calm place is one of nature's condensers. The air there is, during the rainy season, as damp as vapor can make it.

There are certain classes of goods liable to damage in such a damp and warm climate, even during the mere transit, and a larger class that stowage there would ruin. These objections apply also to Nicaragua, but not by any means with equal force, or to such an extent, for this simple reason—its rainy season is not so long or so severe, its climate is not so damp, and its dew-point by no means as high. Many classes of goods, if shipped under canvas from Panama in the rainy season, would be damaged ere the vessel could clear the calm; not so from Nicaragua.

* "Maury's Sailing Directions," 8th edition, 1859, p. 777.
† Ibid.
‡ Ibid,, p. 778.

Of all the climates of America, the climate through which the Panama road runs is the most pestilential. Few places in the world are so sickly as to give their names to disease. We hear of the Asiatic cholera and the coast fever of Africa; but the fermini of the Panama road are the only places in America that have won this unenviable distinction. The Chagres fever on one side, and the Panama on the other, are known throughout the coasts of that continent, and dreaded by all who visit there.

The "Transit route of Nicaragua" is exempt from these heavy drawbacks of dampness and disease. It passes through a salubrious climate. The soil is productive, its pastures abound in cattle. I never heard of any disease peculiar to the country, nor of especial virulence there.

Both its soil and climate are adapted to the cultivation of coffee, sugar, rice, tobacco, cocoa, indigo, and the like, while in its forests you may gather drugs and spices, with ornamental and dye woods of rare beauty and excellence. These, this route will in the process of time bring into the channels of commerce, and convert into valuable sources of revenue. The Panama railroad has developed no feeders, and its wayside business, in a commercial light, is simply *nil.* It would be very different in Nicaragua.

The Pacific termini of the two routes thus present marked contrast; but with the exception of the "northers," those in the Carribbean Sea offer none worth considering as regards the winds and currents. The harbor accommodations of the Nicaraguan transit appear to be superior to those of Aspinwall; moreover, the former is completely sheltered from the violent winds of that coast, while Aspinwall is open to all their fury, although even the harbor of Aspinwall appears to have answered its purpose.

To conclude, you see the sum of all these disadvantages of the Panama route, expressed by the road itself. It has been opened about twelve years; but sailing vessels go and come by the old routes, as though it were not, and they double Cape Horn in greater numbers than ever. Few are the cargoes of merchandise to or from the east, that have found their way across that road. And though its earnings are enormous, it has, as a commercial highway, disappointed the world and the expectations of its advocates from the time of Columbus down; he thought the "gates of ocean" were there, and his day dreams, as he lay ill with the fevers for which Chagres and Panama have won notoriety, were to "unbar" them. It has not altered a single old route of commerce, but it makes enormous dividends for all that.

That a single track of railway should be enough to do the business between the two great oceans, indicates, in language more telling than I can utter, that there must be, in its way as a commercial thoroughfare, practical drawbacks and difficulties of some sort which the world has overlooked. These I have endeavored to point out.

As a mere pecuniary investment, the Panama railway has, in spite of its drawbacks, turned out to be a profitable one. But it derives its profits, not from the lap of commerce, as its friends supposed it would, but chiefly from the transportation of passengers, mails, and express parcels. Open the "Transit Route of Nicaragua," and that will give a new vent to commerce, besides attracting trade that Panama can never win; it and the Panama route will act and re-act favorably upon each other.

For reasons of State, her Majesty's Government should encourage this work. Nationally, it is of great importance. But upon this aspect of the case it would be out of place for me to dwell.

Respectfully, etc., etc.,

M. F. Maury.

30 Harley street, Cavendish square, July, 1866.

The Great Northern Railway (British) Company has adopted a system of lighting railway carriages for long distances by gas, compressed in vessels containing naphthaline. The system employed has been developed by Mr. Sugg, of Westminster, and practical experiments are now being made with it. The advantages of this system, if any, over the Pintsch's oil gas system—employed on about 500 carriages on the Continent, on our own Metropolitan, and in 250 carriages of the Great Eastern Railway, with supply for thirty-five hours' run—is not stated.

TECHNICAL EDUCATION IN ENGLAND, FRANCE AND GERMANY.

From "The Journal of Science."

The City of London Guilds and other corporate bodies seem at length to be convinced of the absolute necessity of adopting some measures for the advancement of technical education in England. As far back as the Paris International Exhibition of 1867 our English masters and workmen awoke to the fact that the leading position which we had formerly occupied as makers of the world's goods was being endangered by the talent and enterprise of foreign nations. The first note of alarm was sounded by Dr. Lyon Playfair, in a letter addressed to Lord Taunton, the chairman of the School Inquiry Commission then sitting. The aim of this communication was to inquire whether England was really losing her high position in those industries which involve the application of scientific knowledge to production; and, if so, whether this retrogression was due to our comparative backwardness in the diffusion of a knowledge of applied science amongst the working classes. The British Commissioners appreciated the warning at its proper value, and, taking advantage of the presence in Paris of some of the most eminent British men of science of the day, they consulted them on the subject, the result being that, with scarcely a single dissentient voice, they affirmed that the lack of technical education on the part of British masters and workmen was slowly, but surely, undermining the position of Great Britain as mistress of the industrial arts.

Speaking generally these salutary warnings have been neglected, although in some few isolated instances they have been duly acted upon. These praiseworthy efforts have for the most part been the work of individuals, and as such have only wrought good in particular localities, anything like a combined action being entirely wanting.

Amongst the latest utterances on this vitally important subject, the paper on "Apprenticeship Schools," read by Prof. Silvanus Thompson before the British Association at Sheffield, and just republished in pamphlet form,* and the Address of Prof. Ayrton at the opening of the City and Guilds of London Institute,† are the most striking. The gist of these able contributions to our knowledge of the subject is that our present system of apprenticeship is utterly rotten, and must speedily be replaced, under the penalty of seeing the whole of our trade with foreign nations gradually drift away from us. During the last half century apprenticeship, as it was understood by our forefathers, has ceased to exist except in name. The master of the present day, unlike his predecessors, seeks his own benefit instead of his apprentice's, and looks more to what he can make out of him than what he can teach him. A boy of fourteen enters a workshop, willing and anxious to learn his trade; for the first year or so he finds himself in the position of a mere errand-boy, or at any rate the servant instead of the pupil of his superior. As soon as another apprentice can be found to do his drudgery he is set to some particular branch of work, and if the shop be a large one he will very probably be kept at it till the end of his term. He is placed under a workman from whom he learns but slowly, seeing that his teacher, being constantly employed on his own work, has but little time to teach him,—the evil reaching its highest point in places where piecework is the rule. It is no one's duty to teach him, and, as it formed no part of the contract between employer and employed, the journeyman very justly refuses to expend any very great portion of his time in instructing his master's apprentice in the secrets and mysteries of his handicraft. As for the master, the boy received no help from

* Apprenticeship Schools in France. By Silvanus P. Thompson, B.A., D.Sc., F.R.A.S., Professor of Experimental Physics, University College, Bristol.

† The Improvements Science can effect in our Trades and in the Condition of our Workmen. By Prof. W. E. Ayrton.

him, even supposing that he is competent to teach him. He consequently picks up his knowledge of one small branch of his trade in an unintelligent and desultory manner, and leaves the workshop at the end of seven years capable of doing only one thing, and that by rule-of-thumb, just as his shopmates have done before him. How differently things were managed in what may truly be called the good old days of apprenticeship! In those times the master was also a workman, and labored at his craft. He had learned every branch of it, and understood it so thoroughly as to be able to teach it to others. Capital and steam have together created gigantic factories, and the old domestic workshops—in which each worker formed part of a kind of family—gradually became the exception; the master craftsman became the mere employer, and the apprentice the boy worker.

The connection between the depression of trade in skilled industries and the question of proper technical education, as well as the hopelessness of attempting to galvanize the old system of apprenticeship into life, is well pointed out by Mr. George Howell in the "Contemporary Review" for October, 1877.

The question now is, what modern substitute for the old system can be adopted to the wants and wishes of the nineteenth century? Prof. Thompson's investigations happily enable us to lay before the reader the actual results of certain experiments recently made in France with a view to organizing a new system of apprenticeship that shall be more in accordance with the social conditions of the present day. These results prove that the systematic instruction of apprentices is possible in several different ways; that apprenticeship schools afford a most satisfactory way of attaining this result; and, lastly, that the new system solves the problem involved in the decay of the old apprenticeship. The problem to be solved, briefly stated, is this:—How to give artisan children the technical training and scientific knowledge which their occupation demands, without detaining them so long at school as to give them a distaste for manual labor. The problem may be solved in four ways, all of which have been tested:

First. We may apprentice children at an earlier age than at present, making it obligatory that all through their apprenticeship they shall every day have a certain number of hours of schooling in a school attached to the workshop.

Secondly. The children may be kept at school for a longer period, on condition that they shall pass a certain amount of time in a workshop attached to the school.

Thirdly. We may organize a school and workshop side by side, an equal number of hours being devoted to manual labor and study.

Fourthly. We may send the children for half the day to the existing schools, and the other half to work half-time in the workshop or factory.

The first of these plans strongly commends itself to our attention, for the knowledge imparted in the school could be correlated to the work done in the factory, to the manifest benefit of both the employer and the employed. This system has been tried in France for the last thirty years, and the establishment of MM. Chaix & Co., the French Railway Guide printers, may be cited as a type of the whole. MM. Chaix's typographical school—for such it really is—has been in existence for seventeen years, and has supplied nearly a hundred able workmen to the firm itself, and the few who have left have found exceptionally good situations. The apprentice is bound for four years, the employers guaranteeing him a place when he is out of his time. They are divided into two classes, compositors and printers. Close to the composing and press-rooms there is a school-room, where the apprentices of both classes spend a couple of hours daily, either in improving their knowledge of the three R's or in going through a technical course of typography, including grammar, writing and composition, reading and correcting proofs, the study of the different kinds of type, and so on. They are also taught to read and set up in type Greek and Latin, without any attempt to instruct them grammatically in these languages; and they are taught the rudiments of English and German. Lastly, there is a course on such subjects as the history of typography, or mechan-

ics, physics, and chemistry, as far as they apply to printing machinery and processes. During the three years the apprentice compositors receive from 5*d.* to 2*s.* per day, and the printer apprentices from 7½*d.* to 3*s.* 8*d.* At the end of the term most of the apprentices prefer to remain in the employment of the firm, and can then earn from 3*s.* to 6*s.*, according to their ability. Great pains are taken to systematize the teaching. The compositor apprentices are set to work under the direction of a foreman, whose chief business is to instruct them, and not to work for his own or his employer's benefit; he is, in fact, a professor of printing, just as Professor Thompson is a professor of Physics.

MM. Chaix's establishment, it must be understood, is only one of over two hundred similar schools in different parts of France, in which a similar system of instruction is given in the manufacture of optical instruments, shirts, jewelry, paper, Italian paste, ribbons, calicoes, plate glass, silks, bookbinding, and a dozen other branches of trade.

A great impetus has been given to this kind of apprenticeship schools by the passage of a law, in 1874, forbidding the industrial employment of children under twelve, except they receive two hours schooling per day; nor may children over twelve and under fifteen be employed for more than six hours per day, unless they have finished their elementary education, their employers being made personally responsible for carrying out these regulations.

In the school of M. Soufflot, a jeweler, the character of the instruction is purely technical. The success which has attended the "school on the workshop system," as Professor Thompson aptly calls it, must not only be extremely gratifying to all who have the cause of technical education at heart, but it must also prove to the attentive observer that, being the most natural, it will eventually become the best system of all.

The second type of school includes those in which systematic instruction in one or more handicrafts is given to boys who are still going on with their elementary instruction. There appears to be one school of this sort in Paris, which is carried on most successfully as far as it goes, only about 12 per cent., however, of the pupils receive manual instruction. They work alternately at carpentering, woodturning, forging, filing, chipping, and metal-turning for two years; after which they specialize their work. They also receive instruction in modeling and technical drawing, and in the summer they visit the neighboring factories. On the completion of the preliminary two years they are draughted off into one of the three special workshops in which modeling and carving, carpentry and wood work, and iron and metal work are carried on under the superintendence of master workmen who have made the teaching of their various crafts a special study. One of the disadvantages of this type of school is, that the instruction given is professedly only preparatory to, and not a substitute for, an ordinary apprenticeship. In its favor it must be conceded that it shortens the long and useless years of apprenticeship, and thus helps the young worker to become a bread winner.

The third system is where the school and the workshop are placed side by side, so that the hours given to study should be co-ordinated with an equal number of hours of manual instruction. This type of school Prof. Thompson thinks is the *apprenticeship school* of the future. France affords two good examples of this class; one the Paris Municipal School of Apprentices, where several distinct trades are taught; and the Besancon Municipal School of Horology, where clock and watch making alone are taught. Taking the Paris school first, we find that the apprentices are only admitted between the ages of thirteen and sixteen. They must also have a certificate showing that they have completed their elementary education, or else undergo an examination. In comparison with schools of the second type a larger amount of time is devoted to the workshops, which are here much more extensive and complete. The course is a three years' initiation into the handicraft taught, and the majority of the pupils leave the school able workmen. The trades in which direct instruction is given are those of the carpenter, wood turner, pattern maker, smith, fitter and metal burner. That the school turns out excellent workers may be judged from the fact that the average age of the pupils

who left the school in 1877 was 17½ years, and their average earnings in the places they had obtained was 3*s*. 1½*d*. per day, one boy of seventeen getting as much as 5*s*. 4½*d*. per day as a smith. The instruction is entirely gratuitous, and the whole of the necessary tools, machines, books, etc., are supplied by the Municipality. The system pursued in the school appears to be of the very highest order, and should serve as a model for all future schools of the kind. The Besancon School of Horology is managed on similar principles, and is a striking success. The school is managed and supported entirely by the Besancon Municipality. In addition to instruction in every branch of horology, the apprentices receive lessons in their own language, arithmetic, algebra, geometry, physics, chemistry, mechanics and drawing, in so far as they relate to horology.

The only system remaining for consideration is that of half-time schools; the system has, however, been almost discarded in this country, and has only been partially tried in France. One radical defect in it is, that there is no correlation between the work done in the factory and the information imparted by the schoolmaster; the whole of the pupils, whether they are intended to be mechanics, dyers or painters, all receive the same kind and quantity of instruction.

So much for the good work that is being done in France, which of all European nations is certainly in the van with regard to lower technical education.

In September last Prof. Thompson visited Germany in compliance with the advice of Mr. Mundella, who, in criticising his paper at the British Association, placed the German technical schools above the French. Prof. Thompson paid visits to the Polytechnicum and Weaving Schools at Chemnitz, these being the special establishments pointed out by Mr. Mundella, and found, as he expected, that although the higher technical training schools in Germany were superior to those elsewhere, they could show nothing in any way equal to the Paris Municipal Apprentice School described above.

Prof. Thompson's investigations have been so thorough, and led to such practical conclusions, that they should receive the serious consideration of those whose business it will be to organize either national or local systems of technical education.

The movement of the city companies has resulted in the setting aside annually of £15,000 for the promotion of technical education, and there has been duly constituted "The City and Guilds of London Institute for the Establishment of Evening Classes for Technical Education, or the Application of Science to Industry." Twelve lectures on "Some of the Practical Applications of Electricity and Magnetism," by Mr. W. E. Ayrton, A.M., Inst. C.E., and twelve lectures on "The First Principles of Chemistry," by Prof. H. E. Armstrong, Ph.D., F.R.S., are now in course of delivery. Subsequent courses of lectures on "The Elementary Principles of Mechanics exemplified in our Clocks and Watches," on "The Applications of the Laws of Heat to the Steam and other Engines," and on "Inorganic Chemistry with especial reference to its Technical Applications," have already been arranged.

We trust this example will be followed in our large manufacturing towns, and that when the best system of imparting technical education has been determined, no red tapeism will hinder it from being speedily and universally adopted. England will then soon regain her former position. Even the Japanese have, as Mr. Ayrton remarks, set us an example that our ambition should lead us to emulate. There has grown up, in the very midst of a people who a few years ago were almost in a state of slavery, a technical college, with its staff of carefully chosen English professors, with its laboratories, class-rooms, museums, libraries and workshops, costing for maintenance an annual sum of £12,000. To study at this college neither money nor position is necessary; ability and a desire for knowledge are the only qualifications.

Boxwood in Russia.—Boxwood grown in the forests on the shores of the Caspian Sea, is, says the *Gardener's Chronicle*, a large article of trade with Russia. This wood reaches Astrachan and Nizni-Novgorod in the spring of the year, where it is sold during the fair. Last year the quantity so sold was about 130,000

poods, being about 80,000 poods in excess of other years. It is pointed out in a recent report that the increased demand for this boxwood, which is used for shuttle-blocks, indicates increased prosperity among Russian manufacturers. On the subject of boxwood, the acting British Consul at Tifflis writes: "*Bona fide* Caucasian boxwood may be said to be commercially non-existent, almost every marketable tree having been exported. Such exorbitant terms are demanded by the government for the right of cutting in one or two remaining Abkhasian boxwood forests as virtually to bar their acquisition." He goes on to say that having personally visited these forests he is in a position to assert that their real value has been considerably exaggerated, most of the trees being either hollow or knotted from age, and much of the best wood having been felled by the Abkhasians previous to Russian occupation. The boxwood at present exported from Rostov, and supposed to be Caucasian, comes from the Persian provinces of Mazanderan and Ghilan on the Caspian. What has been said respecting boxwood applies equally to walnut burrs, or "loupes," for which the Caucasus was once famous, 90 per cent. of which now come from Persia. The walnut trees of the forest along the Black Sea, which are extraordinarily numerous, and afford excellent material for gunstocks, do not, from some climatic peculiarity, produce burrs, which are only found in the dryer climates of Georgia, Daghistan, Persia, &c. The immense quantity of walnut timber in the forests on the Black Sea is mostly unavailable from the complete absence of roads or means of transport, and the dearness and scarcity of labor.

REPORTS OF ENGINEERING SOCIETIES.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—The December number of "Transactions" is at hand.

Its pages are mostly filled with discussions of paper No. 180, "On the Construction and Maintenance of Roads" by Edward P. North.

A valuable note on the "Nomenclature of Bitumens" by Mr. North is added; also some illustrations of various forms of Stone Crushers.

THE ENGINEERS' CLUB OF PHILADELPHIA.—During the past year the membership has been largely increased, the Club has moved into new and commodious rooms, and the experiment of publishing Proceedings has proved highly satisfactory. The library has been largely increased by contributions from members, authors and publishers, and there have been received in exchange for the "Proceedings" copies of reports and proceedings of nineteen engineering societies and the current numbers of twenty-one periodicals, including all the principal engineering magazines.

The tellers appointed to supervise the annual election reported the following gentlemen elected officers of the Club for 1880:

President—Mr. Frederick Graff.
Vice-President—Mr. Percival Roberts, Jr.
Recording Secretary—Mr. Wilfred Lewis.
Corresponding Secretary and Treasurer—Mr. Chas. E. Billin.
Board of Directors—Mr. Rudolph Hering, Mr. Coleman Sellers, Jr., Mr. Howard Murphy, Mr. Geo. Burnham, Jr.

LIVERPOOL ENGINEERING SOCIETY.—The usual fortnightly meeting of this society was held at the Royal Institution, Colquitt street, on Wednesday evening last, the 5th inst., Mr. M. E. Yeatman, M. A., president, in the chair, when a paper, entitled "Notes on Sewers and Sewage," was read by Mr. E. H. Allies, Member of the Association of Municipal and Sanitary Engineers and Surveyors. The author divided his subject into four parts: (1) Drainage works both ancient and modern; (2) the sewer in its relation to public health; (3) the form, construction, and ventilation of sewers; and (4) the disposal of sewage. After glancing at the construction of sewers by the Romans and others down to our times, the author went on to show how great an effect the sewer had on public health, and how important it is that work of this description should be properly designed, carried out, and kept in repair. He treated at considerable length of the ventilation of sewers, and the various methods proposed from time to time for effecting this object, advocating the system of open grid ventilators at frequent intervals, and condemning the use of charcoal in lever ventilators. In conclusion he treated of the disposal of sewage, and showed how the difficulty of dealing with this part of the question has increased of late years. The author does not believe in any of the chemical treatments of sewage being made to pay at present, in proof of which he stated that at least nineteen-twentieths of the sewage of Great Britain is still thrown away. He advocated agricultural irrigation as the least expensive mode of disposing of town sewage when there is no direct outlet to the sea, and gave the area required for this purpose per head of population.

THE INSTITUTION OF CIVIL ENGINEERS.—The Council of the Institution of Civil Engineers have awarded the following premiums for the session 1878-79:

FOR PAPERS READ AT THE ORDINARY MEETINGS.

1.—A Watt Medal, and a Telford Premium, to George Frederick Deacon, M. Inst. C.E., for his paper on "Street Carriage-way Pavements."

2. A Telford Medal, and a Telford Premium,

to John Bower Mackenzie, M. Inst. C.E., for his paper on "The Avonmouth Dock."

3.—A Watt Medal, and a Telford Premium, to James Nicholas Douglass, M Inst. C.E., for his paper on "The Electric Light applied to Lighthouse Illumination."

4.—A Telford Medal, and a Telford Premium, to Adam Fettiplace Blandy, M. Inst. C.E., for his paper on "Dock Gates."

5.—A Telford Premium, to Edward Dobson, Assoc. M. Inst. C.E., for his paper on "The Geelong Water Supply, Victoria, Australia."

6.—A Telford Premium, to James Price, M. Inst. C.E., for his paper on "Movable Bridges."

7.—A Telford Premium, to John Evelyn Williams, M. Inst. C.E., for his paper on "The Whitehaven Harbor and Dock Works."

8.—The Manby Premium, to John Purser Griffith, Assoc. M. Inst. C.E., for his paper on "The Improvement of the Bar of Dublin Harbor by Artificial Scour."

FOR PAPERS PRINTED IN THE PROCEEDINGS WITHOUT BEING DISCUSSED.

1.—A Watt Medal, and a Telford Premium, to George William Sutcliffe, Assoc. M. Inst. C.E., for his paper on "Machinery for the Production and Transmission of Motion in the Large Factories of East Lancashire and West Yorkshire."

2.—A Watt Medal, and a Telford Premium, to Edward Sang, for his paper on "A Search for the Optimum System of Wheel Teeth."

3.—A Telford Premium, to William George Laws, M. Inst. C.E., for his paper on "The Railway Bridge over the River Tyne at Wylam, Northumberland."

4.—A Telford Premium, to George Higgins, M. Inst., C.E., for his "Experiments on the Filtration of Water, with some Remarks on the Composistion of the Water of the River Plate."

FOR PAPERS READ AT THE SUPPLEMENTAL MEETINGS OF STUDENTS.

1.—A Miller Prize, to Arthur Cameron Hurtizg, Stud. Inst. C.E., for his paper on "The Tidal Wave in the River Humber."

2.—A Miller Prize, to Robert Henry Read, Stud. Inst. C.E.. for his paper on "The Construction of Locomotive Boilers."

3.—A Miller Prize, to John Charles Mackay, Stud. Inst. C.E., for his paper on "The Excavation of a Tunnel in Rock by Hand Labor and by Machinery.

4.—A Miller Prize, to Percy Wilson Britton, Stud. Inst. C.E, for his paper on "The Design and Construction of Wrought Iron Tide Arches."

IRON AND STEEL NOTES.

THE yield of iron ore in the kingdom of Prussia during the past year was 2,955,872 tons, raised from 549 pits, and employing 21,991 hands. The number of charcoal furnaces is 44, of which 33 were in blast during 1878, the consumption of home ore being 74,013 tons, and of foreign ore 1,370 tons. The production of pig from these charcoal furnaces was 14,192 tons. The coal and coke furnaces numbered 184, of which 128 were in blast. The yield from these was 1,534,830 tons of pig, of which 54,983 were foundry pig, 426,816 Bessemer pig, open-hearth pig, and spiegeleisen, and 1,040 830 mill pig. Two furnaces have also been running on mixed fuel, making the total pig iron production for the year 1,568,061 tons, smelted in 163 furnaces, and employing 12,992 hands. There were also 571 foundries, employing 19,415 men. Wrought iron is made in 264 establishments, employing 36,540 men, and the production was 1,123,171 tons. In the steel trade, 25 out of the Bessemer converters were in operation during the year, together with 442 open-hearth furnaces and 25 crucible furnaces. The total production of Bessemer steel was 452,399 tons, and of open-hearth steel 51,731 tons. The crucible steel trade was stagnant during the year, only 74 crucibles being in operation out of 282 existing.

NITROGEN IN STEEL.—Whether nitrogen is an essential, or even an occasional, constituent of steel, is a question which has not yet been settled; and after recounting what has been done by previous investigators, the author describes the method of procedure which he prefers. The process has consisted in dissolving the steel in hydrochloric acid in an apparatus from which the air had previously been completely expelled In this manner any combined nitrogen in the metal would be converted into ammonia, which would partly remain dissolved in the liquid and partly pass off with the hydrogen evolved. Any loss from the latter cause was avoided by passing the evolved gas through a tube filled with glass beads moistened with hydrochloric acid. When the solution of the metal was complete, the liquid was distilled with excess of quicklime, and the ammonia in the distillate determined by Nessler's method. This extremely delicate test for ammonia was unknown at the date of previous researches on the existence of nitrogen in steel. Its employment enabled Mr. Allen to operate on a much smaller quantity of steel than was used by previous operators, and it facilitates the operation in every way. Very special precautions were taken to obtain the hydrochloric acid and other materials free from any trace of ammonia or nitrous compounds, and it was directly proved by experiments that no source of ammonia existed in the reagents or apparatus. On determining in this manner the nitrogen in samples of commercial steel and iron, more or less nitrogen has, so far, always been found, varying in most instances from 0.005 to 0.015 per cent. of the weight of the metal, amounts which would be wholly overlooked by many methods of working.

METHODS OF HARDENING IRON AND STEEL.—Experience has shown that the effect of hardening mainly depends upon the content of combined carbon in the iron, upon the differences of temperature between the iron or steel and the hardening fluid, and further on the rapidity of the cooling. The last-mentioned again is dependent on the quantity of the hardening fluid, its specific gravity, power of conducting heat, specific heat, boiling point, and heat of vaporization. Of the four liquids, mercury, water, oil, and coal-tar, therefore, the

first-named hardens much more powerfully than water, water considerably more powerfully than oil, and oil more powerfully than coal-tar. Further, the hardening power of water is altered not only by differences of temperature, but also by the addition of different substances which change its properties in the respects just mentioned. Finally, the rapidity of cooling, so important for the degree of hardening, is also dependent on the way in which the piece is held down into the hardening fluid. The rapidity of the first cooling, from the 600 deg. to 700 deg. C., to which steel has commonly been heated to 300 deg. to 400 deg. C., has a manifold greater influence on the degree of hardness than the succeeding cooling to, say, 60 deg.

RAILWAY NOTES.

THE Gothard tunnel heading was, on January 1st, within little more than 400 meters of completion; but the difficulties encountered during the last few weeks, owing to faults and to influx of water, will very considerably retard the junction of the two headings. It seems that a bed of soft material which has been met with in the tunnel is causing the most trouble by its exudation and transmission of the pressure as by a semi-fluid due to the super-incumbent rock masses.

RAILWAY ACCIDENTS.—The Board of Trade has issued a summary of the accidents and casualties which have been reported to the Board as having occurred upon the railways in the United Kingdom during the nine months ending September 30, 1879. The number of persons killed and injured during that period was as follows: Passengers—From accidents to trains, rolling stock, permanent way, etc., 412 injured; by accidents from other causes, 53 killed, 470 injured. Servants of companies or contractors—From accidents to trains, rolling stock, permanent way, etc., 2 killed, 73 injured; by accidents from other causes, 303 killed, 1,286 injured. Persons passing over railways at level crossings, 46 killed, 19 injured; trespassers, including suicides, 224 killed, 98 injured; other persons not coming in the above classification, 27 killed, 62 injured—Total, 655 killed, 2,420 injured. In addition to these, the railway companies have reported to the Board of Trade, in pursuance of the 6th section of the Regulation of Railways Act, 1871, that 31 persons were killed and 1,586 injured upon their premises, but in these accidents the movement of vehicles used exclusively upon railways was not concerned. Thus, the total number of personal accidents reported to the Board by the several railway companies during the nine months amounts to 686 persons killed and 4,006 injured. Accidents to trains, rolling stock, permanent way, etc , caused the death of three persons and injury to 485, viz., passengers, injured, 412; servants of companies, killed, 2; injured, 73; other persons, killed, 1. During the nine months there were reported 24 collisions between passenger trains or parts of passenger trains, by which 98 passengers and 5 servants were injured; 55 collisions between passenger trains and goods trains or mineral trains, engines, etc., by which 1 servant was killed and 166 passengers and 22 servants were injured; 15 collisions between goods trains or parts of goods trains, by which 18 servants were injured; 61 cases of passenger trains or parts of passenger trains leaving the rails, by which 39 passengers and 3 servants were injured; 6 cases of goods trains or parts of goods trains, engines, etc., leaving the rails, by which 1 servant was injured; 7 cases of trains or engines traveling the wrong direction through points, by which 34 passengers and 6 servants were injured; 13 cases of trains running into stations or sidings at too high a speed, by which a man who had come to a station on business was killed and 58 passengers and 2 servants were injured; 3 cases of the bursting of boilers, or tubes, etc., of engines, by which 1 servant was killed and 5 were injured; 937 failures of tires, by which 2 servants were injured; 346 failures of axles, by which 3 passengers and 2 servants were injured; 13 failures of couplings, by which 7 passengers were injured; 2 failures of ropes used in working inclines, by which 1 servant was injured; 1,377 broken rails, by which 1 passenger and 3 servants were injured; 21 slips in cuttings or embankments, by which 3 servants were injured; and 5 other accidents, by which 6 passengers were injured. Under the heading of accidents to passengers from causes other than accidents to trains, rolling stock, permanent way, etc., including accidents from their want of caution or misconduct, accidents to persons passing over level crossings, trespassers, and others, it appears that 349 persons were killed and 649 were injured, and that 53 of the killed and 470 of the injured were passengers. Of the latter, 17 were killed and 44 injured by falling between carriages and platforms, viz., 9 killed and 30 injured when alighting from and 8 killed and 14 injured when getting into trains; 5 were killed and 320 injured by falling on to platforms, ballast, etc., viz., 5 killed and 290 injured when alighting from and 30 getting into trains; 14 were killed and 6 injured while passing over the line at stations; 42 were injured by the closing of carriage doors; 8 were killed and 22 injured by falling out of carriages during the traveling of trains; and 9 were killed and 36 injured from other causes; 46 persons were killed and 19 injured while passing over railways at level crossings, viz., 30 killed and 15 injured at public level crossings; 12 killed and 3 injured at occupation crossings, and 4 killed and 1 injured at foot crossings; 184 persons were killed and 98 injured when trespassing on the railways; 40 persons committed suicide on railways; and of other persons not specifically classed, but mostly private people having business on the companies' premises, 26 were killed and 62 injured. During the nine months there were 303 servants of companies or contractors reported as having been killed and 1,286 injured, in addition to those included in the first category of accidents.

THE surveys for the proposed railway over the Brunig are now complete, and the work will probably soon be taken in hand. The line will start from Brienz, and run by Mey-

ringen and the Brunig Pass to Garnen, Alpnach, and Staad, on the Lake of the Four Cantons. The steepest gradient will be 12 in 100, the total length of the line will be twenty-five miles, and by the adoption of a gauge of one meter and the avoidance of tunnels, it is estimated that the cost of construction will not exceed £10,000 per mile.

ORDNANCE AND NAVAL.

HER MAJESTY'S SHIP "MERCURY."—The new steel despatch vessel Mercury, which is being completed for sea at Portsmouth, was tried under way on three days in August, the first day being devoted to power and the others to speed.

In material, construction and dimensions, and in the power and description of her machinery, the Mercury is a sister ship to the steel despatch vessel Iris, which has completed her trials at Portsmouth and is ready for commissioning. The only difference has reference to appearance and is a mere matter of detail of no practical importance. The Iris has an overhanging bow, a figure-head being placed on what is termed the "knee of head," while the Mercury has a perfectly straight stem. She was built at Pembroke from Mr. Barnaby's designs, and is engined by Messrs. Maudslay, Sons & Field. As was the case with the sister ship, everything has been surrendered in the Mercury in order to secure a high rate of speed. She is entirely unprotected, her entrance and run are as fine as a racing yacht, and her machinery, which fills the major portion of the hull, is guaranteed to develop 7,000 on her trial trip. She is built of Landore mild steel, and measures 300 feet between perpendiculars, 46 feet 1 inch in extreme breadth, 16 feet 3 inches in hold, and has a displacement of 3,750 tons. Her armament will consist of ten 64-pounders, including a couple of revolving chase guns, which will be mounted on the forecastle and the poop. The engines for working the twin screws are a novelty, so far as the navy is concerned, and are located in separate engine-rooms, divided by a water-tight doorway, the starting platforms of each pair of engines being situated conveniently close to the door. There are in all four high-pressure cylinders, having a diameter of 41 inches, and four low-pressure cylinders, with a diameter of 75 inches, the stroke being 3 feet. Each of the former is bolted to the front of the low-pressure cylinder with which it works, and, for the sake of economizing space, is partly recessed into it. One piston rod carries the two pistons, an arrangement which has been found the best adapted for working at high rates of expansion without any jolting of the moving parts. Each engine, however, is complete in itself, and can be used as a single engine in case of injury to its companion.

This trial can scarcely be said to possess the same interest for engineers as the experimental cruises of the Iris in 1877-8. Built on the same lines and engined in precisely the same manner as her predecessor, her performances under defined conditions of power and screw could have been well-nigh foretold. The Iris was tested under way with four varieties of twin propellers, and the screws which have been fitted to the Mercury are the four-bladed screws of the third series of experiments which gave a speed of 18.57 knots, with 7,714 of indicated horse power. These results, it is true, so far as speed on the measured mile was concerned, were subsequently surpassed by the works of a special two-bladed screw, which gave 18.587-knots, with 7,556 indicated horse power, but the small improvement in speed under full power did not compensate for the increased vibration produced throughout the ship at all speeds except the maximum. No. 3 screws were, therefore, adopted, though, had time permitted, it was Mr. Wright's intention to continue the experiments. The diameter was 16 feet 3½ inches, while the pitch at the forward edge of the blades was 18 feet 11½ inches, at the after edge 20 feet 11½ inches, and the mean pitch as measured 19 feet 11½ inches. The disc area of the blades was .288 of the whole disc. The blades were curved aft a little towards the tips, with a view of keeping the points rather further away from the A brackets, and of checking, in some degree, any centrifugal tendency of the water acted upon. The blades, which were constructed of gun-metal, were polished on both sides to reduce friction, and the edges were made sharp. The original bosses to which the blades were attached had each a conical tail-piece added. The vessel left the Tidal Basin at half-past 7 o'clock for a six hours' continuous full power trial, and after clearing the harbor the engines were gradually worked up to full speed. The trial commenced at a quarter past 8, a run being made down the Channel as far as St. Alban's Head. The force of the wind was from 3 to 4, and the direction abeam, the sea being quite smooth at the time. The draught was 15 feet 8 inches forward and 20 feet 6 inches aft, which was precisely the trim of the Iris during her experimental trips. At the preliminary run the mean pitch of the screw was fixed at 20 feet 8 inches, from which 7,025 horse power was realized. This was so far satisfactory, as the result showed 25 horses over the contract; but, as the engines could not take all the steam that was generated, and still better results were expected, the Mercury was subsequently docked and the pitch confined to 20 feet, which, again, was the pitch of the Iris's fans in the trial to which allusion has already been made Singularly enough, the engines could have taken more steam than could be obtained, the mean number of revolutions per minute having increased from 91 to 95.

The results were scarcely as satisfactory as at the preliminary trial, for while some of the observations showed that the engines were indicating 7,396 and 7,268.6 horses, the mean of the whole run gave a total indicated power of 6,953.07 (that is, 3,514.14 by the starboard and 3,438.93 by the port engines), or a little below the guaranteed power. It will be seen that only on two occasions did the pressure in the boilers reach 65 lbs., to which the safety-valves were loaded, while near the end of the trial the pressure fell as low as 58 lbs. The cause of this was undoubtedly a failure in the supply of the smokeless coal which is generally used on

steam trials and the necessity for resorting to North-country coal. By these means not only was the heat in the furnaces reduced, but the tubes partly choked by the thick smoke. The vacuum was exceedingly regular and satisfactory, the mean being 27.43 inches in the starboard and 27.14 inches in the port condensers. The other means were:—Steam in starboard cylinders, 39.737 and 11.087 lbs.; and in port cylinders, 39.341 and 10.85 lbs.; revolutions, 95.5 starboard, and 94.5 port. A mean of a couple of runs on the mile in Stokes Bay gave a speed of 18.055 knots. These runs were made during the 10th and 11th half hours, when the steam pressure was low, and when the feed to the boilers had become somewhat irregular. (The coal consumption averaged 2.35 lbs. per indicated horse power per hour.) The steam steering gear was found to act admirably, one man being able to steer the ship, where otherwise sixteen would be required to get the rudder over 15 degrees. By steam power the helm is put hard over 24 degrees. In the course of the day Mr. Wright took observations of the obstruction produced by the struts of the propeller tubes, which are not in the same plane with the water.

Although the Government officials were well satisfied with the working of the engines during the six hours' run, it was thought desirable to try the ship for speed on the measured mile, and thereby institute a comparison between her performances and those of the Iris. This trial was made on Thursday, and led to some astonishing results. The day was exceedingly boisterous, the wind having the force of between five and six, and the sea rather rough. The direction of the wind was west-south-west, and thus almost directly ahead and astern during the runs in Stokes Bay. Staff-Commander Parker was the officer in command, the other officials, with the exception of Mr. Wright, who was not present, being the same as on the previous day. After an hour's preliminary cantering, the ship was placed upon the mile with the following results, the boiler pressure being 64.75 lbs.:—

	Revolutions.	I.H.P.	Knots.
First Mile.....	97	7471.09	18.274
Second Mile...	98	7451.78	19.149
Third Mile....	97	7537.97	18.848
Fourth Mile...	98	7594.98	18.750

The mean of all the means gave the remarkable speed of 18.876 knots per hour, thereby beating the Iris (which realized a mean speed of 18.54 knots), and proving the Mercury to be the swiftest full-sized ship afloat in any navy of the world. Indeed, it is difficult to conceive of a ship of her size being driven through the water at the rate of close upon 22 miles an hour. The horse power developed was also more than satisfactory, since the mean reached a total of 7,513.95, which is greatly in excess of the contract, the mean revolutions per minute being 93.44 starboard and 97.26 port, and the average vacuum, 27.5 starboard and 27.12 inches port. The engines were subsequently worked with the jet injection, the results obtained being 4,214.92 horse power, 80 revolutions and a vacuum 25 and 23.5 inches. The exhaust into the low-pressure cylinders was next cut off, and all the eight cylinders worked direct from the boilers, as common engines, for the purpose of ascertaining with how low a pressure the machinery could be worked in action. The pressure in the boilers was reduced to 60 lbs. above the atmosphere, and was then gradually further diminished to the atmospheric pressure. Under the latter conditions 60 revolutions were obtained. The engines were next stopped, and started again at 5½ lbs. above the atmospheric pressure; and were afterwards worked at full power to bring the ship into harbor. Before the close of the trial, however, the engines were stopped, the starboard engine in 34 seconds and the port in 37 seconds, being stopped they were started ahead in 12 seconds and 10 seconds respectively; and going astern they were started ahead in 17 seconds and 10 seconds. The whole of the second day's steaming proved a gratifying success.

BOOK NOTICES.

ROUGH WAYS MADE SMOOTH. By R. A. PROCTOR. London: Chatto & Windus, 1880. For sale by D. Van Nostrand. Price, $2.25.

We have here another series of Mr. Proctor's lively and popular essays on subjects multiform and mix, ranging in the present instance from the Sun's Corona and his Spots and the Past History of the Moon, to Oxford and Cambridge Rowing and Mechanical Chess Players. Whatever may be thought of the author's theories and antipathies, there can only be one opinion as to the felicity of his method. Some of the matters treated of are among the most abstruse; but they are presented in such a way as to be easily understood by, as well as interesting to, the ordinary run of mortals. In the paper on electric lighting we have a popular account of the principles and apparatus of one of the most attractive inventions of the day, and one which has apparently more than most excited the popular imagination. That on mechanical chess-players is also well worth perusal, and one or two psychological questions are ably handled, while the articles on Cold Winters and Great and Recent Storms, have the additional merit of being opportune.

A TEXTBOOK OF FIELD GEOLOGY. By W. H. PENNING, F.G.S. Second Edition. London: Balliere, Tindal & Cox, 1879. For sale by D. Van Nostrand.

The author of this text-book, who is engaged on the Geological Survey of England and Wales, possesses special qualifications as an instructor of geological amateurs who wish to extend their investigations beyond mere fossil-hunting, and to test geological theories by practical observations in the field. To be able to do this is to have acquired an accomplishment that gives a peculiar charm to every country ramble, turning the landscape itself into a book in which its ancient history can be read. The instructions

given are very full and complete, the *instrumenti belli* are described, and their uses explained. The mode of geological surveying is set forth in detail, including divers "wrinkles" as to the way of readily getting at desiderated information when it does not appear exactly on the surface, as well as map-making and the identification of rocks by their lithological structure. Where fossils, the "medals of creation," occur, the student will find ample guidance in the appended section on Palæontology by Mr. A. J. Jukes Browne, who treats of the nature of fossil remains, instructs how to collect them, and shows the nature and importance of the information they supply. In the concluding section the importance of field geology is enforced, certain difficulties connected with it discussed, and its practical results shown. The illustrations of the volume include a colored geological map and a number of sections and diagrams.

TORPEDOES AND TORPEDO WARFARE: Offensive and Defensive. Being A Complete History of Torpedoes and their application to Modern Warfare. By C. SLEEMAN, Esq., late Lieutenant R.N., and late Imperial Ottoman Navy. New York: D. Van Nostrand. Price, $8.

This is an entirely new book, on a subject about which the public at times feel an absorbing interest, and which never ceases to attract the attention of military men everywhere.

How fully this treatise represents the present state of progress in torpedo making, the following table of contents will perhaps sufficiently indicate:

CHAPTER I.—The early History of the Torpedo—Remarks on the existing state of Torpedo Warfare.

CHAPTER II.—Defensive Torpedo Warfare—Mechanical Submarine Mines—Mechanical Fuzes—Mooring Mechanical Mines.

CHAPTER III.—Defensive Torpedo Warfare, continued—Electrical Submarine Mines—Electrical Fuzes—Insulated Electric Cables—Electric Cable Joints—Junction Boxes—Mooring Electrical Submarine Mines.

CHAPTER IV. Defensive Torpedo Warfare, continued—Circuit Closers—Firing by Observation—Voltaic Batteries—Electrical Machines—Firing Keys and Shutter apparatus—Testing Submarine Mines—Clearing a passage through Torpedo Defences.

CHAPTER V.—Offensive Torpedo Warfare—Drifting Torpedoes—Towing Torpedoes—Locomotive Torpedoes—Spar Torpedoes—General Remarks on Offensive Torpedoes.

CHAPTER VI.—Torpedo Vessels and Boats—The "Uhlan"—The "Alarm"—The "Destroyer"—Thornycroft's Torpedo Boats—Yarrow's Torpedo Boats—Schibau's Torpedo Boats—Herreshoff's Torpedo Boats—Torpedo Boat Attacks—Submarine Boats.

CHAPTER VII.—Torpedo Operations—The Crimean War (1854-1856)—The Austro-Italian War (1856)—The American Civil War (1861-1865)—The Paraguayan War (1864-1868)—The Austrian War (1866)—The Franco-German War (1870-1871)—The Russo-Turkish War (1877-1878).

CHAPTER VIII.—On Explosives—Definitions—Experiments—Gunpowder—Picrie Powder—Nitro-Glycerine—Dynamite—Guncotton—Fulminate of Mercury—Dualin—Lithofracteur—Horsley's Powder—Torpedo Explosive Agents—Torpedo Explosions.

CHAPTER IX.—Torpedo Experiments—Chatham, England, 1865—Austria—Carlscrona, Sweden, 1868—Kiel, Prussia—England, 1874—Copenhagen, Denmark, 1874—Carlscrona, Sweden, 1874-5—Portsmouth, England, 1874-5—Pola, Austria, 1875—Portsmouth, England, 1876—Experiments with Countermines—The Medway, England, 1870—Stokes Bay, England, 1873—Carlscrona, Sweden, 1874.

CHAPTER X.—The Electric Light—The Nordenfelt Torpedo Guns—Diving.

CHAPTER XI.—Electricity.

APPENDIX.—McEvoy's Single Main Systems—Siemans' Universal Galvanometer Tables—Synopsis of the principal events that have occurred in connection with the History of the Torpedo—Index.

The work is a large octavo with fifty-seven full page illustrations, besides numerous woodcuts.

SEWERS AND DRAINS FOR POPULOUS DISTRICTS. By JULIUS W. ADAMS. New York: D. Van Nostrand. Price, $3.00.

No branch of engineering is so intimately related to the health and comfort of the residents of large towns, as that of drainage, yet the literature pertaining to it is by no means abundant. There has been no deficiency in general and vague suggestions as to what is desirable in the treatment of sewage, and much confusion of mind will result from reading a collection of the accepted authorities upon this topic; but of the method of solving the problem of efficient *drainage*, stated so as to prove serviceable to the young engineer, too little has thus far been written to satisfy the wants of the profession.

The reason of the deficiency is upon reflection quite obvious. The subject is one that can only be justly treated by a professional engineer of unusual sagacity, and of a ripe and rare experience. Without these qualifications, the ability to write upon engineering subjects, or to wield skillfully the most refined methods of mathematical analysis, lead in this field of labor to no useful results. The final formulas are of necessity in the strictest sense empirical.

Col. Adams has unquestionably brought to bearupon this work the order of talent necessary for a serviceable guide for the profession. In beginning he thus states the problem:

"The modern system of sewage contemplates the construction of a system of impermeable conduits, which, with the water supply to dwellings, and at times the rainfall on the surface, shall prove adequate to the prompt removal from the sites of human habitation, and before time shall be afforded to set up any dangerous fermentation, all excretæ and refuse from human, animal, or vegetable life—everything, in fact, putrescible to be found in the vicinity of dwellings—to some outlets, to be further dealt with by natural or artificial means in order that they may not prove a source of mischief to the residents of other localities.

This method is known as the 'water-carriage system'; and as the solid fæces adds no appreciable amount to the bulk of the house-sewage, so the house sewage calls for no appreciable increase in the capacity of the sewer to carry it off, beyond such as is necessary for the acommodation of that amount of the storm-waters as modern improvements in habitations requires to be carried off in a definite time. This eliminates the consideration of the extent of the population on an area to be drained, and leaves the dimensions of the sewers to be controlled measurably by consideration of the character and extent of that area. Closely-built and paved districts will affect the result only so far as contributing the proportion of the rainfall due to its area in less time after its fall than that from suburban districts. The further consideration of this in its bearing on the dimensions of sewers will be noted subsequently.

The points which demand our attention may be stated as follows:

First.—The area and physical outlines and controlling features of the district to be drained; its geological character, and the depth to which it may be desirable that the drainage should extend.

Second.—The rainfall in the district, with consideration of the maximum fall of rain in a given interval of time, and the proportion of such storm-waters as it is proposed to carry off by the sewers.

Third.—The character and extent of the water supply.

Fourth.—The final disposal of the sewage."

Each of these "points" is treated fully but concisely. There is no lack of clearness in the writer's statement of his deduction from observation, nor does he obscure his mathematical formulas by any devices of integration. Nothing can be plainer than the processes employed or than the reasons for them.

The question of house drainage receives its share of attention, and is well illustrated.

The work deserves, and will doubless receive, a wide circulation.

A Treatise on Fuel, Scientific and Practical. By Robert Galloway, M.R.I.A., F.C.S., &c. London: Trübner & Co. 1880. For sale by D. Van Nostrand. Price, $1.50.

This volume is founded on a course of lectures delivered by the author during his professorship in the Royal College of Sciences, Dublin, and is intended for advanced students and for manufacturers. It is, perhaps, not difficult to trace the part which was originally published in the lecture-room, and which shows that Professor Galloway possesses the rare art of popularizing science; but that elementary portion has been supplemented by much valuable matter of a more practical character, and the resulting handbook cannot fail to be useful to all to whom its subject is of interest, either theoretically or economically. All the substances employed as fuel consist almost wholly of woody tissue, the tissue of recent vegetation being unaltered, and that in peat and the different varieties of coal being in a more or less altered form. Recent timber, and even the stems of grasses, are employed to a considerable extent, in this and other countries, to produce motive power; peat is less frequently used, and it, as well as coal, is employed in the production of charcoal or coke. The former, however, cannot be economically substituted for coal in this country, owing to its bulky nature and the water it retains, even after being thoroughly air-dried. The most important of all fuels, coal, varies very much in character. Some of it approachee very closely to recent wood; other varieties, again, contain so much extraneous matter, as, for example, the Torbane mineral, that their right to be called coal is disputed. Even the most bituminous coals differ in composition so greatly, that for important manufacturing purposes some of them are almost as valueless as peat. Coking coal, for instance, is inapplicable for many furnace operations from its choking up the bars and thus impeding combustion, and where coal contains much pyrites, besides other drawbacks, it corrodes the furnace bars. Lignite is a late deposit, varying in physical character from that of the more compact peats to that of the bituminous coals, which are the most valuable and abundant of all. These, again, are divided into caking or coking, and free-burning coals. Cannel coal, to which division the Torbane mineral already referred to belongs, contains a large proportion of hydrogen and other volatile matter. Anthracite, which is found in the lowest portion of the carboniferous formation, is a species of natural coke, containing 90 per cent. or more of carbon. Coal always contains in its pores a variable quantity of gas. That in the Welsh steam-coal is highly inflammable, and evolved to a great extent after the coal has been raised, hence the danger of carelessly shipping it. The decomposition, which allows the gas thus to escape, has been generally attributed to the oxidation of iron pyrites contained in the coal. Professor Galloway agrees with Dr. Percy that it is rather due to the oxidation of the organic substances of the coal itself. Chapter II. is devoted to an elaborate exposition of the methods employed for determining the heating power of fuel, and the instruments used for that purpose; and the author afterwards shows that from causes specified, the total theoretical heating power is never obtained in practice. In the two succeeding chapters the principles of construction of pryometers and Siemens' regenerative gas-furnaces are lucidly described, the technical examination and analysis of coal are explained, and a description of Orsat's gas apparatus is given, with the tables employed in calculating the results.

A Treatise on Mountain Roads, Live Loads and Bridges. By Lieut.-Gen. H. St. Clair Wilkins, R.E. London: E & F. N. Spon. 1879. For sale by D. Van-Nostrand.

This very exhaustive treatise is printed at Bombay, and the illustrations are taken from Indian constructions. In countries like Hindostan, where railways must always be chiefly main lines, roads are necessary, not only for

local intercommunication, but as railway feeders. These are either ordinary or mountain roads. The principles of construction of the former have been pretty well ascertained; but that is not the case with the others which have been rarely made according to any fixed principles. These the author proposes to supply. The first step is to reconnoitre the site of the proposed road, the plan of which varies according as it is to traverse an approximately level, undulating or mountainous district. For this full and judicious directions are given, and then for the detailed survey. The various classes of road are next defined, their several breadths indicated, and the mode of construction described. Their maintenance and repair form the subject of a separate chapter, and the cost of roads of each class and crossing various descriptions of the country is elaborately investigated. Live loads are next examined and compared, and examples are given of the different live loads on trussed girders, which the author considers well suited for road works in a forest country; but he holds that an iron bridge should never be erected where the conditions for a masonry one are suitable, the latter being cheaper and more permanent. Copious and comprehensive as this work is, the author informs us that it is not a mere compilation, but that the opinions expressed and the designs given are the results of his personal experience. That must have been an extensive and useful one; and by putting it thus on record he has rendered an important service to the public as well as to those who may be called upon to perform similar tasks. The volume is illustrated by a score of full page cuts, showing sections or elevations of roads and bridges.

HISTORY AND MYSTERY OF PRECIOUS STONES. By WILLIAM JONES, F.S.A. Richard Bentley & Son. 1880. pp. 376. For sale by D. Van Nostrand.

The vulgarization of precious stones is one of the most difficult tasks which the restless leveling spirit of the nineteenth century has set itself. If, as yet, it seems to be weaving a rope of sand, like Michael Scott's indefatigable familiar, there is no denying the fact that progress of an amazing character has been made in mineralogical synthesis. French skill has reproduced meteoric ironstone, pyroxene diopside has been got from the "Thomas" basic brick, garnets and rubies have been made in the laboratory, and the secret of crystallizing carbon is said to have been so shrewdly guessed at that the incubation of diamonds will by and by be as common an industry at Glasgow as sugar boiling. For the present, however, the romance of gems is safe from the spoiling hand of the manufacturer, if, as we desire to do, we may repose our faith on Dr. Percy's assurances, and continue to believe in the inimitable perfection of Nature's workmahship.

On the eve of Mr. McTear's revelations, however, the publication of the present work has a certain appropriateness of contrast which gives its reading an extra piquancy. All the old superstitions connected with gems are recounted, the coloring is shown which they have given to poetry and romance, to religion and to history. Leaving to the mineralogists all scientific detail, Mr. Jones has occupied himself with the archæology and the romance of gems, and has brought together and admirably classified a vast amount of scattered, often recondite, facts and fictions concerning these "flowers of the mineral world." The style is pleasant and gossipy, neat withal, and elastic enough to bear the weight of the erudition it often has to carry. The chapter devoted to the "philosophy" of gems is not the least entertaining; we are sorry, however, that it leaves undiscussed the momentous question, May a gentleman, or may he not, wear a diamond ring?

MISCELLANEOUS.

THE following formula for the brilliant white enamel applied sometimes to French cards and *papier de luxe*, and which might be useful for coating models of wood, etc., is given in the *Paper Trade Circular*. For white, and for all pale and delicate shades, take twenty-four parts by weight of paraffine, add thereto 100 parts of pure kaolin (China clay), very dry, and reduced to a fine powder. Before mixing with the paraffine the kaolin must be heated to fusing point. Let the mixture cool, and it will form a homogeneous mass, which is to be reduced to powder and worked into a paste in a paint mill with warm water. The enamel is then ready for application. It can be tinted to any desired color.

IN his report of the fatal accident which attended the use of dynamite in the Severn Tunnel on the 23d of September, Major Ford, inspector of explosives, expresses his opinion that the deaths were caused by the evolution of nitrous acid fumes, produced partly by firing and not properly detonating the dynamite. He considers that other noxious vapors, as carbonic oxide and acid, may have contributed to the deaths of the men, whose symptoms were very similar to those of a number of others whose cases he describes. The report is very complete and exhaustive and interesting to those interested in the use of explosives.

IVORY may be silvered by immersing it in a weak solution of chloride of silver, and letting it remain till of a deep yellow color; then take out and dip in water, after which expose to the sun's rays until black. On rubbing, the black surface will soon change to a silver.